Agricultural Research Institute

PUSA

HAND-BOOK

OF

COMMON SALT.

COMMON SALT.

BY

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Second Edition
REVISED AND ENLARGED.

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As my salt experiences, are, for the most part Indian—Indian illustrations, and Indian colouring, will naturally characterize my work, but I have avoided the use of Indian technicalities and phrases, as much as possible. I have acknowledged in the text, wherever necessary, the authors, to whom I am indebted for information, and I have thus been enabled to dispense with the use of foot-notes.

J. J. L. RATTON.

MADRAS, 1st *October* 1877.

PREFACE TO SECOND EDITION.

The first edition of the Hand-book of Common Salt having been exhausted, thanks in a great measure to the patronage of the Indian Governments, and especially of the Madras Government, which has placed it on the list of text books for the examination of candidates in the Salt Department, I now venture to bring a second edition to the notice of the Public.

A late tour in Europe has enlarged my acquaintance with salt mines in England and Ireland, the salt and alkali manufactures in Cheshire, the bay salt works of Britanny and those of the Mediterranean, in France. I have also freely availed myself of all printed sources of information on the subject of common salt to be found in public libraries. Especially am I indebted, in this respect, to the magnificent library of the British Museum.

By these recent experiences I have been led to make such large alterations and additions to the Hand-book of Common salt that, in its present shape, it is more a new work, than a new edition of an old one. The Historical chapter, the chapters relating to the Hygiene of salt, its employment in the Arts, Rock Salt, the Sea and the Salt Tax, have been entirely re-written. A new and very important chapter has been devoted to the Agricultural use of salt. The chapters on Associated Minerals, and Chemical Analyses, on Subsoil Brine and Brine Springs, and those on Spontaneous

Salt and Earth Salt, have been amalgamated. And a variety of changes and improvements have been made in every other part of the work.

Although the faults and imperfections of the first edition have been carefully sought for and removed, I am quite sure that other faults will replace them in the present work; I must, therefore, ask the critic to be lenient, whilst trusting that the reader will find no errors too serious to be forgiven. It is right that I should mention, here, that I was employed by the Madras Government for five years, exclusively, in examining different methods of bay salt manufacture; and that I have been for the last ten years engaged, more or less, in the study of the subject of Salt, as this is the *raison detre* of this book.

In conclusion, I have to thank my kind friend Mr. Harold Stuart, M.C.S., for great assistance, in correcting proof sheets, and for the philological information to be found in the Appendix.

MADRAS, *October* 1882.

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COMMON SALT.

CHAPTER I.

HISTORICAL.

A good deal of research has been devoted to clearing up the early history of common salt. An account of its genesis or geological birth, will be found in the Chapter on the sea. Here we have to deal with it in its relation to the human race; and in this respect, it is found that a history of salt is, to some extent, a history of civilization. We can trace salt back in the past as far as the pages of history extend. The Egyptian, Mosaic, and Chinese records refer to it repeatedly; and beyond the papyrus leaf tablets and inspired writings we lose it in the mists which surround the history of primitive man. Here, however, philology comes to our assistance, and throws a negative, but not uncertain, light upon its early history.

In Sanskrit, and in allied languages, the common root of salt words is altogether wanting. All the old languages represent salt by dissimilar names. In Chinese and Japanese salt is called *Jan, Jen,* or *Jam.* In Sanskrit, *lavanam.* In Malay and Javanese, *gâram.* In Red Indian, *oonhabet.* In Hindustani it is called *nimuck:* also *romrus* and *noon,*

according to its qualities. In Persian, *lön.* In the Tamil language, *uppu.* In Nagary, *lahbanah.* The Celtic name for salt was *halle;* Greek, αλσ, or hals. One of the oldest tribes of the Indo-Germanic race was called *Halloren* from its connection with salt. The Latin word *sal,* salt, is cognate with the Celtic *halle.* So, also, are the following modern words,—French, *sel:* German, *salz:* Dutch, *sout:* Russian, *sahl:* Spanish, etc., *sal:* and English, *salt.* From these indications of diversity in the expression of the idea, salt, in the oldest languages, and the want of a common root for salt words, we are led to infer that salt itself was unnoticed, and unused, by primitive man. Sea salt, lake salt, and even rock salt, may have been known; but they excited no interest, for as yet they supplied no want.

Our earliest ancestors lived in a wild, hand to mouth way, eating with omniverous instincts, the fruits of the earth, the flesh of animals and birds, and fishes, when, and where, they found them. They did not at first cook their food. It was eaten raw, until they became acquainted with the use of fire, and burnt-offerings. It was not boiled till long afterwards. This is a diet that needs no salt. Fruits have their own salts; and flesh meat is rich in sodium chloride, or common salt. Raw meat, according to Enderlin, (Carpenter's Physiology) contains 4·4 parts common salt, per thousand; and dried meat 19·4 parts. Hence carniverous animals lack the instinct for salt: they get enough in the flesh they consume. So also monkeys, birds, and other creatures, that live entirely on fruits. There are many savage tribes still existing who live on half cooked meat, and make no use of salt. Even Homer, (B.C. 900, circa) in his descriptions of the feasts and sacrifices of the polished Greeks, never mentions salt as a condiment, as it was not required with burnt-offerings. The ash of burnt meat, contains

nearly 46 *per cent.* of the chlorides of sodium, and potassium. Primitive man, therefore, had no great need to speak of salt, as he did not eat it. The use of salt, as a condiment, marks a great advance in the progress of civilization.

We must suppose that in the pastoral period of human progress, when men watched their flocks, the dietetic use of salt as regards animals, was known. Wherever cattle could reach salt, they would certainly draw attention to it. But man was still independent of it; his diet was but little altered, and salt as yet bore no well-known name. Sallust observes that the ancient Numidians lived on milk and game, without salt. (*Jugurtha*, 87.) It was not perhaps until that period of civilization indicated by the manufacture and use of *cooking* pottery that salt came to be appreciated as a condiment. This would about coincide in point of time with a certain knowledge of agriculture; or at least with a knowledge of the edible nature of seed grains and vegetables, which require cooking. Probably the knowledge of alimenttary plants came first. On the principle that necessity is the mother of invention, the thing to be cooked, would create the idea of a cooking-pot, and proceed it in point of time. But seed grains and vegetables require more than cooking; they require salt. Green foods, as a rule, are poor in salt. Cereals, which form so large a portion of man's dietary, are especially deficient in sodium chloride. The powerful instinct of herbiverous animals, which leads them irresistibly in search of salt, depends upon the fact that grasses are almost devoid of salt. Given the cooking-pot; and boiled meat follows. But boiled meat, also, requires salt. In boiling, meat loses about 70 per cent. of its salt, parting with it to the water. It becomes insipid and requires the addition of salt to render it palatable. Vegetables and other foods also part with their soluble salts in boiling.

With the earliest use of boiled food, therefore, the want of salt must have been felt by men. Following the instinct of animals, they would use salt water from the sea, or from brine springs, in the first instance, except in the few localities in which solid salt occurs. In the South Sea Islands, at Tahiti, Samoa, and Tonga, the natives still eat fish, raw, dipping them into salt water. (Schleiden, Das Salz, 83). It is likely that, at first, salt was generally used in a similar way, in solution. The salt crystal, itself, which is found encrusting sea swamps, and the neighbourhood of brine springs, would soon, however, become an object of some value. Cattle would draw attention to it by licking it; as also rock salt, where attainable. There is reason to believe that men, copying animals, in this respect also, at first licked crystallized salt. It was not mixed with food in cooking, or used separately in the state of powder, until much later. We gather this from the frequent use of the term *salt licking* in early Greek and Roman writers. (Plautus Curc, iv, 4, 5; Persius, iii, 3, 23; Diogenes Laert, vi, 57; Philostrat, Epist, Apoll, Tyan., 7; Persius, Sat, v, 138; Aristophanes, Equit, 103, 1,089.) Even at the present time salt is licked by the natives of Abyssinia.

If salt came into use with the cooking-pot, the question arises, when did the cooking-pot come into use. Without attempting to give even an approximate answer to a question which touches so closely the disputed points of archæology, it may be noticed, that fragments of pottery associated with coarse flint implements and the bones of extinct animals, have been found in the cave deposits of Belgium. ("The Epoch of the Mammoth," Jas. C. Southall, p. 74.) An urn, with four knob handles, for lifting it, found at Furfooz, is figured on the same page. This urn closely resembles a Madras cooking-pot of the present day. The same

author states that hand-made pottery is found in the lake dwellings of Switzerland. And, M. Von Ecker found pottery, associated with cooking hearths, in the river gravel, near Munzingen, in the Rhine valley, ("Archiv fur Anthrop, August 1875, 5, 87.") These facts would point to the existence of salt cooking in the palæolithic, or first stone age, which Southall shows may have existed some 5000 years ago. He points out that the lake dwellers of the stone age were an agricultural people, "as is proved by the discovery of three varieties of wheat, two of barley, and two of millet." These grains, however cooked, required salt.

Dr. Schlieman's excavations at Hissarlick, the seat of Ancient Troy, throw some light upon this point. He found there five distinct deposits in super-imposed stata, representing five successive epochs of inhabitation. The second from the bottom he identified as the Homeric Troy. Mr. Gladstone assigns the date 1270, B.C. (circa) to the Homeric war which involved this city in ruin. In its ruins were found, besides vessels of gold and silver, a quantity of wheel-made pottery, and *a copper kettle!* In the debris of the older city, beneath it, were found large quantities of Assyrian and other pottery, much of it handsomely designed and ornamented. It is probable, therefore, that cooking was practised in the Troad nearly 4,000 years ago. Whether we look for the origin of man in the palæolithic deposits, or in the ruins of Egypt, Assyria, and Babylonia, we are alike confronted with fragments of pottery in his early relics. As we shall presently see, common salt was known to the Egyptians of the remote dynasties. It is not improbable therefore that salt was used in cooking nearly 5,000 years ago. But if we turn from cooking to the antiseptic, commercial, and sacerdotal aspects of salt, we find more exact sources of information at hand, which take us back to the

threshold of the historic period. We learn from Homer that salt food was eaten in the days when Troy was awake with life.

Food was originally salted to preserve it, and not to season it, though one use may have led to the other. The accidental preservation of dead animals in salt swamps, or salt lakes, would furnish the clue to this property of salt. The *Icthyophagi* of Homer used salt fish : so did the Ethiopians, (Herodotus, ii, 77; Diodor, iii, 16; Hieronymus adv. Iovinian L. ii, c. 7, column 334.) But still earlier records of the antiseptic use of salt are found in Egyptian mummies. These were subjected to a lengthened pickling in salt brine before being enshrouded. Herodotus describes the method of preparing them. (Herodotus, ii, 86, 88, Papyrus Rhind, edit. Burgsch, I, vi, 4.) The bodies of the dead, after the removal of the viscera from the cavities, and the brain matter from the skull, were steeped in a strong solution of salt for seventy days. This prolonged bath was perhaps the most important factor in their preservation. The mummies of the early period were only dried, and not embalmed, yet a fragment of one—a hand—has been found recently in the pyramid of Pepi, the Phiops of the sixth dynasty. It would consequently be about 4,500 years old. Sir S. Wilson and the English Egyptologists fix the first, or Menes dynasty, at 2,700, B.C. The Egyptians in later times had a large salting place at Pelusium. (Schleiden Das Salz, p. 86). The Phoenicians were also well known as fish salters. Phoenician works of the kind were found in Sardinia (Eber's "Phœnicians, and the book of Moses," pp. 120, 126), Historically celebrated examples of the preservation of the human body, by salt, are on record. The body of Anthony was salted and laid in a vault, by Cleopatra; there to be united with her own after her death (35 B.C. circa) Cleopatra left direc-

tions that her own body was likewise to be kept in salt (Dion Cassius, xxxvii, 24 L. 1, 2 L. 1, 15). Pharmaces sent the body of Mithridates, embalmed in salt, to Pompey. (ibid).

From the foregoing facts relative to the antiseptic uses of salt we might expect to find that a trade in salt existed from a very early time. Such is the case; and, moreover, this trade is supposed to have been the earliest form of commercial enterprise. The Egyptian priests considered the salt of Hammomem the purest, and preferred it to sea salt. This, according to Schleiden, is the oldest allusion to commerce in history, (Das Salz, p. 19). The sea salt, here referred to, is that which is formed spontaneously near the sea—swamp salt—not manufactured salt. There is no evidence that the Egyptians were acquainted with the art of making bay salt. Their antipathy to swamp salt is interesting, for as we shall hereafter see, the same dislike exists at the present day amongst the natives of India. The Egyptians obtained their salt by barter, from African salt deposits. In the interior of North Africa a large salt trade existed in the time of Herodotus (Born B.C., 484.) Large Caravans carried salt through the Sahara. The earliest centres of the salt trade were Karta, Bambara, Timbuctoo, and Cairo. The salt basin of the Sahara furnished the salt.

From the trade in salt itself, to that in salt-fish, is an easy transition. We learn that the Egyptians had a commerce in salted Nile fish, resembling sardines. (Herodotus ii, 77; Diodorus i, 36, 53; Pollux Onom, vi, 9; Athenæus Deipnos, iii, 88, pp. 469 and 93.) Herodotus says the Egyptians "live on fish, raw, but sun-dried or steeped in brine; they eat also raw quails and ducks, and the smaller birds, salted beforehand," (Euterpe III, Chap. i, 27.)

We now see that salt has been instrumental in advancing our civilization three important steps, viz., in the direction

of food preservation; the distribution and equalisation of food resources; and the initiation of commerce. And there is reason to believe that these were amongst the earliest steps of human progress in these directions.

At a very early period, also, the hygienic value of salt was recognised, and it had acquired a peculiar significance, as emblematical of virtue; which it retains in some countries to this day. It entered into the sacred functions of the Egyptians, and of the Jews; and was held in great veneration by the Chinese. The Chinese have a salt deity, *Phelo,* with an annual feast in summer. The founder of Buddhism, Sakya Muni, Gotama, or Buddha, who wrote his "Verbal Instructions," about 1,000 B.C. refers figuratively to salt. The washing and preparation for sacrifice of the Egyptians was done with salt water; they also sprinkled the vestibules of their houses with salt water, after washing them in the morning. (Schleiden Das Salz, p. 314.) The Mosaic record, which is supposed to have been written about 1,500 B.C., abounds with references to salt, from the destruction of Sodom, down to the Christian era. The Israelites, in the Old Testament, are frequently reminded of the *covenant of salt.* It was used in the sacrifices of the Temple, by command of the Levitical Law: "Every oblation of thy meat-offering shalt thou season with salt; neither shalt thou suffer the salt of the covenant of thy God to be wanting from thy meat-offering; with all thine offerings thou shalt offer salt."

It is of interest to inquire what kind of salt was venerated in ancient times. Manufactured salt, is clearly out of the question. There is reason to suppose that much of the Biblical salt was rock salt. It exists on the borders of the Dead Sea, where the city of Sodom once stood. The salt, which came into Egypt from the North of Africa, was also

rock salt. The salt rocks of Tegaza, west of the Sahara, still supply the caravans going to Timbuctoo. It is probable, therefore, that this, the purest and the best description of salt, was that to which the ancients attached so many virtues. Alexander the Great noticed that the Indian mountains contained rock salt; and some of these mountains are now riddled with abandoned salt mines of a very ancient date. Salt lakes were also early recognized. Xerxes, in his march through Phrygia, passed a salt lake near Colossæ. (Herodotus, Polymnia, B. vii, Chap. xxx.) It would be difficult to believe that Egypt, the mother of the arts, was ignorant of such a simple matter as the manufacture of bay salt, were it not that Egypt was rich in swamp, and effloresced salt, derived from the sea, and that her people had no need to manufacture salt. Besides, there was the prejudice against sea salt already noticed.

Amara Ghoscha, an Indian Lexicographer, who wrote just before the Christian era, distinguishes four kinds of salt as known in India, at that time, *lavanah* or sea salt, (spontaneous); *Sindhu-ga* or rock salt, from Scinde; *raumaka,* or lake salt, from the district of Rauma; and *Vittavana,* a medicinal salt prepared by boiling. His description holds good at the present day. Pliny, the naturalist, who wrote A.D. 70, noticed the salt lakes of the Caspian and Arral, the rock salt of Sirbonis and Gerrhœ, numerous salt springs, and a method of preparing salt by pouring sea water on glowing embers, (Levinius Lemnus, "de occultis natura miraculis" L. iii, c. 9). The manufacture of bay salt appears to have been first practised by Ancus Martius, (Schleiden Das Salz, p. 10.) At least there is no earlier record of it. It is curious that the art of procuring and refining salt by boiling should have been known before salt making by solar evaporation. The Chinese are reputed to have prepared salt

in this way from time immemorial, from brine springs. Columella instructs how to boil salt. (L. xii, c. 53.) The secret of bay salt manufacture is contained in the writings of Pythagoras, although the art does not appear to have been practised till a late period.

As a matter of course, the ancients had but a vague idea of the origin and composition of salt. It is only in recent years that the chemistry of sodium chloride has been thoroughly understood. Pythagoras says that salt is born of the sun and ocean. (Diogenes Laerteus, viii, 1, 35); Tacitus says that it is the product of the battle of fire and water, (Annal, xiii, 57.) So also Pliny, (Hist. Nat., xxxi, 46, 1.) Very poetical views of its origin, but correct enough as far as they go. Hippocrates is more definite when he says that the sun draws away the fine particles of water, leaving the heavy salt behind.

Having now traced the history of salt to a comparatively recent period, let us examine its position in literature. As might be expected from the halo of mystery surrounding its origin, and the position it had early acquired in the sacred mysteries of Egypt, and the sacrifices of the Jews, it has stamped a characteristic and enduring mark upon literature, which has descended to our own day. It is a remarkably common figure of speech, used metaphorically in several senses, all of a lofty character. Plutarch enlarges on the symbolism of salt, comparing it to the soul which preserves the body in life, as salt preserves it from corruption after death. (Quaest conviv, v. 10, 3.) Homer calls it Thion, or God-like. Zeno, the Greek founder of the Stoic Philosophy, B. C. 300, writes, "a soul was given to the hog instead of salt to prevent his body from rotting." Plato, (Symposion 5,) uses 'salt' in a like way.

Salt is mentioned no less than 27 times in different parts

of the Bible. A study of these references to salt shows clearly, that it was considered in the Inspired Work as something good in itself, and capable of stamping with a solemn impress the most serious transactions of men. The Jews were strictly enjoined to use it with all their sacrifices. Our Lord Himself says, "Salt is good," (Mark, ix, 50), a very remarkable declaration which has not attracted the attention it deserves. Salt has at least three well-marked significations in the Holy Scriptures. It is used as an emblem of fidelity, of wisdom, and of barrenness. Moses says, "It is a covenant of salt for ever before the Lord, unto thee, and to thy seed with thee." As a figure of wisdom, salt is referred to in Colosians, Chap. iv, 6: "Let your speech be always in grace seasoned with salt, that you may know how you ought to answer every man." Our Lord also calls the Apostles "the salt of the earth," (Matt., Chap. v, 13.) And as typical of barrenness, "Burning it with brimstone, and the heat of salt, so that it cannot be sown any more, nor any green thing grow therein after the example of Sodom and Gomorrah, (Deut., Chap. xxix, 23.) When Abimelech destroyed the city of Shechem it is said that "he sowed salt in it," to show how thoroughly he had accomplished the work of devastation, (Judges, Chap. ix, 45.) Many other extracts of a like kind might be made from sacred history.

A high estimate of its hiygienic value may have had something to do with the semi-sacred position of salt. We read that the Hebrews rubbed new born infants with salt, (Ezekiel, xvi, 4.) And when Elisha sweetened the waters of the fountains of Jericho, he cast salt into them, and said, "I have healed those waters," (2 Kings, ii, 21.)

Nor are these views of salt confined to the pages of Scripture. We find them repeatedly cropping up in the writings of pagan philosophers. As regards fidelity, Aris-

totle says, we should eat a measure of salt in friendship, to be sure of our friend. (Ethik Endem, 7, 2, 46, and Ethik Nikom, 8, 3, 8.) Cicero says, we should eat some measures of salt, with the same object. ("Laelius," xix, 67.) "True to his salt," a strong expression of fidelity, in modern English, shows how this idea has lasted. The Roman classic writers make use of salt freely as a figure of wit and wisdom. (Horace, Epistle, ii, 2, 60; Catullus Carus L. xxxvi, 4 and xvi, 7; Cornelius Nep. Att. 13, Cicero Brut, 34.) Cicero says, "Scipio surpassed all in salt and wit." In contemporary writings *Cum grano salis*, is a favourite expression, used to qualify the publication of doubtful statements. It signifies, literally, that they must be taken with a grain of salt, *i.e.*, wisdom, or discretion.

Livy called Greece the *sal gentium* (salt of nations) in compliment to its great pre-eminence in learning and the fine arts. This is perhaps the metaphorical sense in which salt is most generally used now. The common expression *Attic salt*, signifies the wit and wisdom with which speech is seasoned. The Germans speak of a flat uninteresting speech, as *ungasalzene* or unsalted. In the year 1820-21, there was published an Etonian periodical called the "*Salt-Bearer*." Salt is used in the religious ceremonies of the Catholic and Greek Churches, at the present day, as a symbol of wisdom—under the name of *sal sapientiæ*. This is the salt used in baptism. But salt has many other significations in modern literature besides these above-mentioned. Shakespeare, the great master of our own language, uses it in a variety of senses: "Is not discourse, manhood, learning, gentleness, justice and liberality, the spice and salt that seasons man." (Shakespeare.) For tears also "He perfidiously has given up for certain drops of salt, your city Rome, to his wife and mother.

(Coriolanus, v, 6.) As personifying lust:" "Though we are justices and doctors and churchmen, Mr. Page, we have some salt of our youth in us." (The Merry Wives, ii, 3.) Also, "All the charms of love, salt Cleopatra, soften thy warm lip." (Antony and Cleopatra, ii, 1.) And Othelo, ii, 1; iii, 3.

On the other hand we find salt used as a figure of constancy in the Old Testament, Levit., ii, 13; Numbers, xviii, 19; 2 Chro., xiii, 5.) In the Andalusian language salt is synonymous with grace, and one cannot flatter a woman more than to call her a salt-cellar: (Globus, R. Undrèè, Ed., xi, 1867, p. 140.) The use of salt in sacrifice was adopted from the Jews by the early Christian Church. It exists to the present day in the Roman Catholic Church, whose "holy-water," or that which stands at Church doors, and is used in most of the ceremonies of the Church, is a weak solution of salt. Pagan Rome had previously adopted this custom. Pliny tells us that salt was one of the principal things used in the Roman sacrifices. It was especially offered to the Penates, according to Horace, (Ode, iii, 23, also, Livy, xxvi, 36.)

Many of these mystic conceptions of salt survive to the present day in Eastern Nations, especially amongst the Arabs, Turks, and Russians, by whom salt is still used to ratify and confirm mutual pacts and agreements, as an emblem of honour and fidelity. In the story of the "Arabian Nights," Coggia Houssain, chief of the forty thieves, excuses himself from eating supper with Ali Baba, lest he should violate hospitality by partaking of his host's salt. The recent Russo-Turkish war, 1878, brought to light the existence of the covenant of salt in Eastern official quarters. And Baron du Tott remarks that at the present day the Turks eat bread and salt together as a pledge of good faith in their deal-

ings. When the Emperor of Russia visited Moscow, July 30, 1881, at a time of Nihilist troubles, Reuter informed the world that he took bread and salt from the Town Commander before addressing the people.

Closely related to the symbolical position of salt in literature, is its position in ancient and current superstitions. It is wonderful how those superstitions, having their origin in the sacerdotal uses of salt in the far past, have survived to our time, even amongst the most cultivated nations of Europe. Salt is used in exorcisms in the Catholic and Greek Churches, not with any idea of its special value in those cases, but because it enters into nearly all ceremonies of the Church, being contained in "holy water." Hence, it is used to cast out devils.

This practice of the early Christian Church may have given rise to the popular superstition that the devil is afraid of salt. In German mythology salt was considered as a valuable antidote to all charms and spells, (Schleiden Das Salz, p. 78.) Up to the year 1408 the people of France and Germany placed salt with children they wished to abandon, partly to keep evil spirits away, but this was also a sign asked for by the Church to show that the children had not been baptized: (DuCange gloss., S. V. Sal juxta). In Denmark, salt and light were put with abandoned children; and visitors to death-beds put salt on the fire to keep off the devil. In Wales they still put salt on a corpse. Houses are salted for luck. The Eothen, a German tribe, when they suspected their cattle of being bewitched, loaded a gun with salt, and fired it at them, as a counter charm: (Schleiden Das Salz, p. 80.) The Romans used salt in their funeral rites. Plutarch, in Crassus, mentions a curious result of this: the Roman soldiers in the Parthian war, receiving salt with their rations, were frightened, as they

thought it an evil omen, boding defeat and death. In East Prussia, brides still put salt in the pocket of the bridal-dress to keep off evil spirits. The Russians present salt to a newly married bride and bridegroom. In Westphalia, baptismal salt is used for cattle in labour. In Normandy, salt is tied round the horns of cows to increase their milk. The lower peasantry of Westphalia breathe upon a grain of salt and carry it about with them as a healing charm: this custom was once largely prevalent in Germany.

One of the most prevalent superstitions at the present day is that concerning the helping and upsetting of salt at table. Few people are altogether free from it. Some would not help a neighbour to salt lest it should presage a quarrel. Others feel unhappy if they upset the salt-cellar, without knowing why. Some say it is a sign of the devil, and that a little salt must be thrown over the left shoulder into his eye. This is the origin of the old English expression, "over the left!" These ideas were noticed by Bishop Hall in 1608, (Brand's Popular Antiquities). At that time it was thought unlucky if salt fell towards a person. Leonardo da Vinci embodied this superstition in his celebrated picture of the Last Supper, at Milan: painted at the end of the 14th or beginning of the 15th century. Judas Iscariot is there represented as knocking over the salt-cellar in his nervous excitement, as he stretches his right arm, with the money bag, across the table. The idea is as old as the time of Pythagoras, 600 B.C. if not older. Dacre says, in his life of Pythagoras, "Salt was the emblem of justice; for as salt preserves all things and prevents corruption, so justice preserves whatever it animates, and without it, all is corrupt." Pythagoras therefore ordered that a salt-cellar should always be placed on the table to remind men of virtue. The Pythagoreans considered the spilling of this salt a presage of some injustice.

There runs a popular nursery legend, common to the chief nations of Europe, that you can catch a bird by putting salt on its tale. Whence it is derived, no one seems to know; Schleiden mentions it without explanation. The question was mooted in "Notes and Queries" some years ago, but without result.

Besides influencing our literature and superstitions, salt has bequeathed to us certain words in common use. Early Civil Governments took special cognisance of salt. The Celts had a separate officer of high degree in whose hands rested the direction of all salt affairs. They were called *graver* from *grava* or gray hairs, hence the German title of Graaf, or Count. The Romans had an early custom of paying their fighting men with salt, from whence is derived the English word soldier, *sal-dare,* to give salt, French and German, *soldat.* The word salary has a like origin. It springs from the habit, common to Agrippa and other Roman Emperors, of paying for forced labour of any kind, with oil and salt. Salt miners were paid exclusively in kind, hence the word *salarium;* The Roman soldiers, who worked at the salt mine of Droitwich in Worcestershire, received salt for their services. Salad is dervied from *sal,* salt, and *latus, broad,* a broad-leafed alimentary plant, being understood. Salute and salubrious from *salus* may also have the root *sal,* salt. We have already seen that the hygienic value of salt was exaggerated by the ancients, and that it entered into all manner of important transactions, as well as being used in sacrifice. Mungo Park states that he saw salt used in Abyssinia as a kind of *salutation;* travellers, meeting friends, offered piece of salt to taste. The ancient salt box was called *saler,* from whence is derived the modern salt-*cellar.* It is possible that the word cellar, in its common signification, is derived from the same

source, as salt was stored apart with great care. The Romans had a particular servant, called *salinator,* whose duty, it was to attend to the pounding, cleaning and storage of salt. A few centuries ago there existed in the Tower of London, a building called the Salt Tower. We shall see hereafter that salt was an important element in the provisioning of the fortresses of the middle ages. The French *sal* dirty, Irish *salah,* are derived from the same source; and this furnishes a clue to the early history of salt manufacture. Pliny tells us that salt was made by pouring sea water over glowing embers. (Levinius Lemmus, De occultis natura miraculis, L. iii, chap. 9.) This would furnish very dirty salt. Indeed, without going to Historical records, at all, one may find very dirty salt at the present day at many Indian bay salt gardens. It is likely, however, that dirty salt, scraped from the mud of salt swamps, gave birth to this idea for the manufacture of bay salt, seems to be a comparatively recent art.

But it is in the names of places, chiefly, that we recognise the influence of salt. Many old towns in Germany, as Hallein. in Salzburg, derive their names from *Halle* salt, Others drop the H as Allendorf. In our own country, Hayling Island, near Portsmouth, the oldest known site of salt manufacture in England, comes from *Halle* or *Hal,* salt. So also, Halsall in Lancashire, Halstead, Halwick, Halton, etc., etc. The Welsh name for salt is *hel,* and for a salt pit, *heledd,* hence Pullhelli "the salt pools." It is probable that before the Roman invasion (55 B.C.) salt was made in these places by the ancient Celtic inhabitants. The Romans would have used the prefix *sal* to denote a salt manufactory. The Saxons subsequently (A.D. 450,) used the suffix *wic,* Englise *wich.* A large number of English towns whose names terminate in "*wich,*" owe their *origin,* as well as their names, to salt, for

example, Harwich, Sandwich, Greenwich, Norwich, Woolwich, etc. "*Wich*" is derived from the Norse *wig*, Anglo-saxon, *wic*, which originally signified a dwelling place. When the Danish and Norwegian pirates ravaged the English coast, they established themselves on the bays and inlets of the shore to procure salt, and founded hamlets or wigs where they made bay salt. In time the Norse termination *wich* became so completely identified with this industry that on the subsequent discovery of brine springs in Cheshire, the termination "*wich*" was naturally adopted as indicating a salt manufactory. Thus we have Northwich, Droitwich, Middlewich, etc. These and many other flourishing towns, both in England and on the continent of Europe, near salt mines or on the sea, owe their prosperity to common salt. The manufacture of salt from brine springs in Cheshire is known to be older than the time of Edward the Confessor, (A.D.1041.) In the year 816, Kenelph, King of the Mercians, gave Hamilton and the houses in Wich, with salt furnaces, to the Church of Worcester. About the year 906, Edward, "King of England," endowed the same Church with five other salt furnaces. William the Conqueror, A.D. 1066, found a record of the number of salt-works and their proprietors in the time of Edward the Confessor.

Wars on account of the possession of salt sources are on record. The Hermendures and Khats fought for the ownership of salt springs. The Burgundians and Germans had a similar feud. (Schleiden Das Salz, p. 81.) The rebellion of Ghent against the Duke of Burgundy is said to have been caused by the salt-tax. The French Revolution is by some people traced to the Gubelle or Code of salt laws then in vogue in France. The fortunes of war have also been influenced by salt. During the Russian war with Circassia, the Circassians having no salt sources of

their own, and having their salt supply cut off by the Russians, were in consequence subjugated. The Romans punished with death the sale of salt to an enemy. (Pandect, L. xxxix, tit. iv, s. 11.) In England, in the middle ages, the Barons, who were constantly at war with one another, were obliged to lay in a large provision of salt meat in case of siege. Hume tells us that when the insurgent Barons ravaged the estate of the elder Spencer, in the reign of Edward II., they found in his larder the following salt provisions, 600 bacons, 80 carcases of beef, and 600 sheep. We learn from the Northumberland "household book" that in 1512, the family still kept a large stock of salted food.

Salt junk was formerly, and still is, a very important item in the provisioning of towns preparing for siege, armies in the field, and navies at sea. It helped the Parisians in 1871 to prolong the siege of Paris. It has sustained the British tar in the great victories of old. It is still found aiding in the peaceful conquests of the north Pole, forming the chief article of diet in Polar expeditions.

The empire of Venice was in a great measure founded on her monopoly of salt manufacture. The old Republic forced her neighbours to abandon salt manufacture; seized all competing salt works, and destroyed those which she could not work. In later centuries with the conquest of Istria and the Grecian Isles, Venice abandoned her own lagoon salines, and extended those of Greece. With her downfall the salt industry so completely disappeared that the 1st Napoleon, who created the new kingdom, had to import Marseillaise to re-establish the salines.

Some other curious notes regarding salt may find a place here. One would not expect to hear of salt as a building material: yet dwellings and even villages have been built, in the open air, of rock salt. In mines, salt habitations are

not uncommon at the present day. In the Wieliczka Mine, in Poland, they exist on a grand scale. But Pliny tells us the same of Sirbonis and Gerrhæ. (Pliny H. N., xxxi, 39.) Herodotus mentions the rock salt dwellings of ancient Lybia, in the African desert. (Herodotus, iv, 181—185.) At Atacama, near Copiapo, in Chilli, the natives build their huts of rock salt. Chardin says, that in the Sirdar passes, between Teheran and Kischlak, in Persia, it is so dry that habitations of rock salt are constructed for use. Also in the desert of Caramani the natives dwell in huts formed of rock salt. (Chardin, Reese nach Persia, ii, 36.) Whilst cutting the Suez Canal, the workmen came on a bed of rock salt, at the site of lake Timash, which they used to make huts. Captain Govin of the "Messageries Maritimes" informed me that the men found the huts comfortable, and continued to use them for some months.

Salt is used for making ornaments. At the French Salines, on the Mediterranean Coast, very pretty crosses, etc., are made, which crumble away, however, after a year or so, owing to the presence of Magnesium Chloride in sea salt. But at some mines, especially at Wieliczka, very effective ornaments of crystal salt, are made, which are as lasting as alabaster. A statue of St. John Sigismund, made from the rock salt of this mine, braved the vicissitudes of climate at Warsaw, for many years; and it is still preserved at the mine.

Rock salt has also been used as money. It was so used, coined and stamped, on the frontiers between China and Burmah. (Klapproth.) It was also used as a coin formerly in Abyssinia, being at that time a rare and precious mineral in those places. Alvarez, the Portuguese Ambassador to Abyssinia, (1520, 1527,) noticed the use of salt as a medium of exchange; about 60 blocks were equivalent to a cruzado of

Indian, or Portuguese money. (Haklut Society, translation, 1881.)

Bruce notices the same thing in his "Travels, in Abyssinia." He took possession of a pot of food which he found, "leaving in its place a wedge of salt, which strange to say is still used as small money in Gondar and all over Abyssinia." In the first edition of this work the author mentions that in his experience in Abyssinia, with the force under Lord Napier of Magdala, he did not observe the use of salt money. But it should have been noticed that the force carried a large quantity of salt into the country, from which the natives were, at the time, liberally supplied. Mungo Park describes salt on the greatest of all luxuries in Central Africa. Dr. Letheby (Food, New York, 1872,) says, "Amongst the Gallas and on the coast of Sierra Leone, brothers will sell their sisters, husbands their wives, and parents their children for salt. In the district of Accra on the Gold Coast a handful of salt is the most valuable thing on earth after gold, and will purchase a slave or two. Capt. Parry states that he saw one ounce of gold paid for a pound of salt in California in 1849: ("Colonial Experiences," p. 103.)

In the middle ages the alchemists endeavoured to transmute salt into gold. The fruition of this project was in a certain sense, realised early in the present century, when large fortunes were made in England from salt. The class of salt manufactured in England was not particularly good in the middle ages, if we may judge from the fact that prime qualities were imported from the bay salt works of Holland or Zealand. As late as the 16th century, English writers refer in notes of admiration to the Dutch "butter salt" and "salt upon salt." In the year 1670 rock salt was first discovered in England in the lands of W. Madburry, Esq., of Mad-

burry; and later, in 1779, at Lawton in Cheshire. These discoveries gave an enormous impetus to the salt trade of England. Not only were large private fortunes made, but the prosperity of the whole country was influenced in a marked way.

From abundant and cheap salt a number of the arts and manufactures which characterise our civilization at the present day, such as the Alkali works, bleaching powder, &c. have sprung into existence To the food preservation of the ancients, we must now add the use of soap, white paper, white linen, various dyes, glass, pottery, and a variety of arts and manufactures—which will be found enumerated in their proper place—as descending to us in consequence of salt. Besides its influence on trade and social progress, salt has been for many centuries past, an important source of public revenue. The Romans are credited with having been the first to impose a tax upon it. There is not a civilized government in the world which has not since followed in their footsteps. At the present day all the nations, with the exception of two or three, which vary their policy from time to time, derive an income from it. In British India, it is one of the principal sources of revenue, yielding over £7,000,000 annually.

Some ancient salt customs, of interest to the antiquarian, remain to be noticed. When the English Barons, their Esquires, and retainers, dined together at one long table, a salt box placed in the centre, marked the distinction of rank; those who were accounted gentle folk, sat above the salt, whilst their followers sat below it. Hence, a common way in old English of expressing a man's position in life was to say that he sat, "above, or below, the salt." At country feasts the salt box was often extemporised into a kind of noisy musical instrument; old English Chronicles refer to

this *playing on the salt box.* "College salting" was an institution that existed in those days. This term was applied to a barbarous custom of treating freshmen, entering College, to all manner of indignities, including salting. It existed at Oxford as late as the year 1637. "*Salting mines*" is a modern notion, of American origin. It is expressive of the method of giving a fictitious value to mining properties, by stocking them with purchased articles of the kind which they are supposed to produce naturally.

"Salt silver" was the name given to an old English custom of giving a penny at St. Martinmas, to the Lord, in lieu of carrying salt from market to his larder. The custom of "asking for salt" still exists at Eton Montem, a graceful relic of its antiquity. Formerly, the Lord Mayor, or Justice of the Peace, at Quarter Sessions, had power to fix the price of salt for their town, or district, and no one could sell higher, or lower, under a penalty of £20 and imprisonment till paid. There was also a customs duty of 5 per cent. levied on all salt brought to the port of London, called *grainage*, payable to the Lord Mayor.

A few words now as to the amount of salt still available for the wants of man. It has been ages longer in use than coal has: but there is no possibility of its ever being exhausted. Salt is a mineral of universal distribution. Nature has provided it, dissolved in the sea, in springs, and lakes, stored up in the earth in mines, spread out on swamps, or efflorescing on plains, in every part of the world. In point of quantity Karsten placed it after sulphur, but recent discoveries increase its importance. The stores of rock salt laid bare in Europe alone are marvellous in extent; yet Geologists are still reporting fresh discoveries of salt mines in different parts of the world. The sea, it is calculated, contains over 58,000 cubic miles of salt; adding one or two thousand more as the

contents of land deposits, we have 60,000 cubic miles of common salt. Considering the hygienic importance of salt to animals and to man, not to speak of its beneficial influence in manyot her directions, its presence, everywhere, has justly been considered as an evidence of design in the creation of the world.

The following is a list of the books and papers, more or less concerned with salt, which I have had access to. Most of them are to be found in the library of the British Museum. The French works are in the Bibliotheque National, Paris :—

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CHAPTER II.

COMPOSITION AND PROPERTIES.

Composition.—Common salt, or sodium chloride, is a combination of two simple bodies—chlorine, and sodium, in the proportion of 35·5 parts by weight of the former with 23 parts of the latter. These figures represent the atomic weights or combining equivalents of chlorine and sodium respectively; so that 100 parts of the salt will always be found to consist of 60·4 part of chlorine with 39·6 parts of sodium. Chlorine is the electro negative element in the combination, hence the old name, chloride of sodium. Salt does not resemble either of the elements of which it is composed. Chlorine, is a yellow gas. Sodium, is a metal of a silvery lustre, capable of burning in the open air, and burning spontaneously in water. The chemical symbol of common salt is '$NaCl$.' Na. standing for natrium, the old name of sodium, and Cl. for chlorine.

Common salt is called muriate of soda in old works, as the acid with which sodium combined to form it, was then known as muriatic acid, from *murias,* sea salt. We now know that salt contains no acid whatever, being a combination of two simple bodies, or elements. Further, the name "hydrochloric" has long been substituted for the acid formerly called muriatic. Salt is called *sodic* chloride by some modern chemists, because the termination *ic* is short, and it corresponds with continental usage.

Specific Gravity, 2·0 to 2·25.—Its specific gravity is its relative weight, compared, at the same temperature and pressure, with the weight of an equal bulk of distilled water, taken as a standard with the fixed value of 1·0. Owing to defective crystallization it is hard to get two specimens of salt which will weigh alike. Practically, however, salt is twice as heavy as water.

Solubility.—Common salt requires about $2\frac{1}{2}$ parts of water at 60° Fahrenheit for its solution; 100 parts of water dissolve about 37 parts of the salt. Its solubility is but slightly affected by ordinary temperatures. According to Gay Lussac, and Poggiale, its solubility in water increases with rise in temperature to the extent shown as follows:—

		Poggiale.	Gay Lussac.
		Cmmon Salt.	
100 parts of water at	0° Centigrade dissolve	35·52	...
	14°	35·87	...
	$14\frac{4}{9}$°	...	36
	60°	...	37
	100°	36·61	...
	$107\frac{7}{9}$°	...	40·38
	110°	40·35	...

Between 0° C and 100° C, the freezing and boiling points of water, 100 parts of water gain the power of dissolving an extra 1·09 parts of salt, according to Poggiale, who gives 36·61 parts as soluble at 100° C. But as Gay Lussac, and most other observers, agree in stating that 100 parts of water dissolve 37 parts of salt at 60° C—it is probable that the solubility of salt in water is increased 1·5 per cent. between the freezing and boiling points. Both observers agree in showing a sudden increase of solubility, extending to 3·35 parts of salt, between the boiling point and 110° C. (=230° F.)

This shows that the common idea that heat makes no difference in the solubility of salt, does not hold good in

the case of extreme temperatures. A saturated solution, prepared by heating to 110° C, if cooled down o—15° C, will suddenly supersaturate, becoming stiff with the transparent crystals of the hydrate, which renders the liquid so thick that a thermometer can with difficulty be used in it. If the quantity of anhydrous salt contained in the fluid be now examined, it will be found 32·5 parts per 100, showing a difference of nearly eight parts, per cent., soluble, between 15° C and 110° C.

The time required to dissolve salt is lessened by heat. For example, a block of rock salt heated to a red heat and thrown into sufficient water to dissolve it, dissolves almost at once.

Common salt dissolves to a limited extent in spirits of wine, but is nearly insoluble in absolute alcohol.

Its solubility diminishes in the presence of some other salts which have a greater affinity for water, as sodium sulphate, magnesium sulphate, and magnesium chloride; water containing 27·4 parts per cent. of the latter, can only dissolve two parts per cent. of sodium chloride.

Calcium chloride, in solid, or solution, if added to a common salt-solution, precipitates the sodium chloride and takes its place in the solution. Strong hydrochloric acid acts in the same way, discharging the salt.

Deliquescence.—Pure sodium chloride is not deliquescent; nevertheless as the great bulk of common salt, as it is found in commerce, moistens in a moist atmosphere and is popularly supposed to do so of its own motion, it is necessary to notice the subject here. It moistens owing to the presence of a minute quantity of magnesium chloride, one of the most deliquescent of all known bodies, an impurity which is very constantly present in common salt, and most difficult to dislodge. Common salt is therefore, generally,

a good hygroscope; that is, by its condition as to moisture, it indicates whether the atmosphere is moist or dry. It should never absolutely deliquesce or form water. When it passes from the state of dampness to that of moisture and beads of water form on it, which coalesce and form streams, it is a sure sign that the salt is very impure and is badly manufactured if it is of artificial origin. Some of the pure seams of crystal salt, worked in the Cheshire and Austrian mines, are noted for their dryness; the workmen suffer a good deal from the dry salt dust which floats in the workings and irritates the lungs and eyes. At Wieliczka, in Poland, crystals of rock salt of exceptional purity are found in large blocks; these have been carved into all sorts of models, statuary, etc., which remain for generations intact in the mine. Amongst these is the statue of King John Sigismund, a work of some historical and artistic interest, already mentioned. In the various subterranean Chapels at Wieliczka, there are numbers of statues carved from the crystal walls of rock salt, in an excellent state of preservation; some of which, as those in the Chapel of St. Anthony, are known to be over a century old. The statue of the Polish Queen, Kunigunda, foundress of the mine, is supposed to be much older.

The older statues are blunt of feature, but this, after all, considering the lapse of time, the nature of the rock, the surrounding impurities, and the rough handling of the miners, subtracts but little from the value of this evidence that pure sodium chloride is not deliquescent.

Diffusion.—Beilstein found the co-efficient of diffusion of sodium chloride to be 0·833, as compared with potassium chloride, 1·000. From a 1 per cent. solution of sodium chloride, he found that 6·17 grains diffused in seven days, at a temperature of 63·4° Fahrenheit. As his experiments refer

to the most important salts of sea water, they are noted in detail here. Beilstein's experiments.

Substance.	Per Cent. Solution.	Temperature Fahrenheit.	Days.	Diffused in grains.
Sodium chloride ...	1	63·4°	7·	6·17
Magnesium chloride ...	1	50·8°	11·43	6·17
Magnesium sulphate...	1	65·4°	16·17	7·31

Beilstein gives the following co-efficients of diffusion to the undermentioned salts :—

Potassium chloride ...	1·000	Magnesium sulphate ...	0·350
Sodium chloride ...	0·833	Magnesium chloride ...	0·404
Sodium sulphate ...	0·536		

Some experiments by Her V. Wroblewski, who has made a special photometric study of the diffusion of sodium chloride, are described in Wien Ann, No. 8. Wroblewski points out the importance of this work to the establishment of a kinetic theory of fluids. He employed Hüfner's spectrophotometer, and nigrosin as colouring matter, where the amount of salt was extremely small. Attention is drawn to the discordant results obtained in this field by previous experimenters. For example, taking numbers expressible in absolute units, the co-efficient is stated to be—

$$\left.\begin{array}{lr} \text{By Graham at } 5^\circ\text{ C} \quad \ldots \quad \ldots & 88 \\ \text{,, ,, ,, } 9^\circ\text{ C} \quad \ldots \quad \ldots & 105 \\ \text{,, Fick ,, ,,} \quad \ldots \quad \ldots & 116 \\ \text{,, Johannisjanz} \quad \ldots \quad \ldots & 53 \\ \text{,, Schumeister, } 10^\circ\text{ C} \ldots \quad \ldots & 97 \end{array}\right\} \times 10-7\frac{\text{cm}^2}{\text{Sec.}}$$

Wroblewski experimented with three solutions of sodium chloride, of which the first contained 0·66487, the second 5·8506, and the third 17·695 parts, by weight, of the anhydrous salt, in 100 parts of the solution. The temperature was 8·5° C, and the duration of the experiment 6·5 hours. The co-efficient found, was, with the first solution—

$$\begin{array}{llll} & 0\cdot66487 & \text{p. ct.} & 768 \\ \text{2nd} \ldots & 5\cdot\ 8506 & \text{,,} & 808 \\ \text{3rd} \ldots & 17\cdot\ 695 & \text{,,} & 889 \end{array}\Bigg\} \times 8\frac{\text{cm}^3}{\text{Sec.}}$$

Hence the constant of diffusion decreases with the diminution of the quantity of salt, according to a law of simple proportion. In the manufacture of salt, by solar evaporation, the strong brine in the salt-pans often shows a difference of 2 or 3 degrees Beaumè in different parts of the same pan; showing that, practically, diffusion is a slow process. The same thing has been noticed in the gulf of St. Lawrence, where zones of water alternate according to their densities, in spite of differences of temperature. At 10 fathoms depth the water in the gulf has a temperature of 375° F. and specific gravity of 1·023. Ten fathoms lower its specific gravity is 1·0246, but it is warmer, 39° F. At 50 fathoms the temperature is 33° F. and the specific gravity 1·026. At 100 fathoms the temperature is 36° F, but the water does not rise as the specific gravity is 1·0275.

Wroblewski says, that when "salt solutions diffuse in water, it is not the salt itself, but the solution which diffuses in the water."

Thermal.—Salt is not decomposed by heat. Pure sodium chloride melts or fuses at a red heat, passing quietly into the liquid state, and forming a solid vitrious crystalline mass on cooling. Ordinary common salt fuses and volatilizes at a low red heat, in the open air, but cakes in closed vessels. Crystals containing fluids or gases decrepitate at a moderately high temperature. At a white heat, salt always volatilizes, even in closed vessels. Salt burns with a bluish flame, but gives the yellow colour of sodium with the blow pipe.

The cause of the blue coloured flame has been discussed in Nature, vol. xix, p. 483. Mr. Percy Smith showed experimentally that it was caused by the presence of hydrochloric acid, which itself burns blue. It was also attributed to carbonic oxide; but Mr. C. Michie Smith, who examined

the flame with a spectroscope, and compared it with that of carbonic oxide, found that the latter contained no bright band, whereas sodium chloride contains four—one pair in the blue and another in the violet. Other salts of soda failed to give these lines, but other chlorides, as Potassium chloride, gave them. The colour is probably, therefore, due to the formation of Hydrochloric acid in the flame.

Karsten finds the freezing, and boiling points of common salt solutions, to vary as follows :—

Parts Pr. Ct. of Salt...	1	5	15	20	25	29
Centgr. Freezing, Pt.	—0·76°	—3·78°	—10·99°	—14·42°	—17·77°	
Centgr. Boiling Pt.,	100·21°.	101·10°.	103·99°.	105·46°.	107·27°.	108·83°.

M. Müller, of the Berlin Chemical Society, finds that a solution of sodium chloride, sufficiently concentrated to have a boiling point of 127° C—a saturated solution—may be raised to 125° C, by passing steam at 100° C through it; that is, the solution becomes 25° C warmer than the agent which warms it. This curious property, which is common to some other saline solutions, has a practical application as regards salt, which gains considerably in solubility when the temperature of its solvent water rises from 100° C to 110° C. By passing steam into the solution, this rise of temperature can be readily effected, and the water made to take up in solution, in every 100 parts, an extra 3·35 parts of salt.

S. Cabot of Boston, U. S. A., found that salt thrown into a cast iron stove, heated with anthracite coal and supplied with oxygen by a stream of mixed air and steam, was decomposed at once into hydrochloric acid and sodium oxide. It is probably a partial decomposition of this kind which liberates the acid and causes the blue flame when salt is burnt on a fire.

When salt is mixed in equal parts with snow or pounded

ice, the melting mass forms what is called a freezing mixture, or one which produces intense cold. In the year 1714, when Fahrenheit invented his thermometer, this mixture afforded the lowest fixed temperature then known, hence Fahrenheit chose it for the zero of his scale. The temperature of the mixture, therefore, corresponds with 0° F. or—17·7° C. It is needless to say that the fall in temperature is due to the sensible heat of all the crystals becoming latent, in their passage from the solid to the liquid state.

Diathermancy.—Transparent salt crystals, even in large blocks, are perfectly diatherminous; that is to say, they are equally pervious to heat rays of every degree of refrangibility, and transmit them without loss, as light is transmitted through clear glass.

Rock salt buildings would seem from this to be remarkably unpleasant dwellings, for they keep out the breeze, whilst the sun's rays beat through them with unrestricted force, and their atmosphere is pervaded with salt. Rock salt habitations, however, are not transparent, for as a general rule rock salt, inb locks, is quite opaque, containing air, gases, which are not diatherminous.

Taste.—Saline, peculiar; conferring an agreeable flavour on all kinds of food.

The taste of salt is remarkably influenced by its surface area and dryness. Finely powdered dry salt, as the best English table salt, is much more pungent than the coarse grained, damp salt, used in kitchens, or ordinary bay salt. As it exposes a larger surface, in the aggregate, to solution, so a larger quantity acts at a time on a given space. The pungency of salt is also increased by the presence of magnesium chloride which is found more or less in all form of sea salt. In India, many of the natives prefer salt, so

affected, and consider it strong salt. Scheliden says, that salt was formerly seasoned or scented with carroway seeds, and that this is still done in some places. (Das Salz, pp. 352, 353). A passage of the Bible, which refers to salt losing its savour, and which has evoked much comment, will receive attention when we come to consider perimorphism. It may be mentioned here that salt has no smell. The agreeable smell of violets given off by the large salt heaps, formerly in Hampshire, and still in Portugal, is due to the admixture of bituminous matter. When salt is in solution, it is not perceptible to the taste in less quantities than 15 grains to the litre, or about 30 grains to the gallon.

Hardness = 2·5. According to Ure's Dictionary, "It is not so brittle as nitre. It is nearly as hard as alum, a little harder than gypsum, and softer than calcareous spar." In the salt mines of North-West British India, in former days, platters, and various other articles, were cut out of rock salt. Dr. Warth, Engineer in charge of the "Mayo" Salt Mines, states that rock salt is like alabaster and capable of being turned on a lathe. At the Wieliczka Mines, the workmen make for their profit and amusement a number of articles, such as crucifixes, rosary beads, books, salt-cellars, billiard balls, inkstands, etc., of the beautiful crystal salt, there found. Many statues and *bas reliefs*, the work of amateur hands, adorn the chapels and galleries of the mine. In 1698 a chapel to St. Anthony was excavated in the mine, all the furniture and decorations of which, including the doors, altar, etc., are of salt. This chapel, when M. Kohl visited the mines, some 30 odd years ago, contained statues of St. Anthony, St. Dominic, St. Francis, St. Kunigunda, of the Bishops Stanislaus and Casimer, and of the Blessed Virgin. The stalls and troughs for the horses of this mine, as in many other Continental and English mines,

are cut out of solid rock salt, which is found hard and durable enough to resist rough usage.

Acoustic.—The acoustic properties of salt, which depend upon its hardness, have not been much noticed. It has a remarkable power of conveying sound, resembling in this respect the metals. Dr. Warth mentions that in the "Mayo" Mines, the workmen are able to signal to each other, in approaching drifts, through 130 feet of intervening salt, by blows on the face of the rock. The Foreman of the Marston Mine gave me a very curious illustration of this power. It seems that, formerly, in Cheshire, the mines were closed on the 1st of May, as that day was considered unlucky owing to mining accidents. One 1st of May, in his father's time, *the mines were all closed, but one,* situated two miles from the Marston. His father was down, minding the horses in the Marston Mine, on that day, and he could distinctly hear the picks, tapping the salt, in the mine at work, *two miles off.* It should be noted that, as far as is known, the whole valley of Cheshire, in those parts, is occupied by one solid mass of rock salt, where untouched by man.

Antiseptic.—Sodium chloride is a powerful antiseptic; that is to say, it has the power of arresting decomposition and putrefactive changes in dead organisms. This property of salt is taken advantage of in the fisheries, where dead fish are preserved by means of salt for exportation, and kept sweet and wholesome for long periods, and through various changes of weather. Meat taken into the interior of salt mines remains sound for a long time, and appears to be preserved by the salt atmosphere. It is stated on good authority that horses thrown into the abandoned workings of the Wieliczka Salt Mines, have been found, years afterwards, in a perfect state of preservation, having been protected from decomposition by the surrounding salt.

Salt in solution has also an antiseptic action. It is found that the ropes in the *Moutier's* brine works, over which brine of sp. gr. 1,040 percolates, remain serviceable for about 30 years.

Professor De Candolle, long ago, drew attention to the preservative powers of boiled sea water. He examined a branch of a coffee plant, preserved for fifty-three years in a liquid, said to be sea water. He found that it was so, but that the sea water had been boiled. From this hint I prepared, about three years ago, an antiseptic solution, consisting of the boiled mother liquor of bay salt manufacture, at 25° Beaumè. To test its power of preserving, I placed in it a human toe, lately amputated: and I find that the toe is now, after three years, perfectly preserved.

Colour.—Pure, anhydrous rock salt is colourless and transparent. Small blocks of perfectly transparent salt are common enough in most mines—and considerable masses of clear salt are found in the Wieliczka and Nevada Mines. A correspondent of the San Francisco *Chronicle*, writes, "On placing a mass six inches thick from the Nevada salt mountains over a column of the *Chronicle*, the fine print could be read easily." Dr. Warth states, that a rectangular polished block of pure salt, 37½ cubic feet, weighing 2⅕ tons, was sent from the "Mayo" Mines to the Vienna Exhibition. In large masses, however, numerous flaws, stains, etc., generally interfere with vision. Rock salt has often a pinkish, or a bluish tinge, from mineral or organic stains. Much of the salt from the "Mayo" Mines is pink in colour. Salt seems to have been found in various mines of almost every colour—red, brown, green, blue, grey, etc. Sea salt, when clean and free from earth stains, is generally white; but becomes opaque from the presence of air, water, etc., in the innumerable fissures and flaws of its ill-jointed crystalline

lamellæ. The clearest salt, when finely ground, looks white from reflected light. Commercial salt should be at least white, or translucent, and have a vitreous lustre. There are many salts manufactured and consumed in the east, however, which do not come up to this standard. Some of these latter have a dark brown or black tinge from admixture with the soil of the pans from which they are taken.

At the Wieliczka Mines small blocks of beautifully clear blue salt, of a sapphire tinge, are sometimes found. They are held in great estimation as rare and valuable specimens. It is not known to what cause the colour is due. It disappears completely when the salt is ground, leaving the crystals white like common salt.

Crystalline form.—Sodium chloride crystallizes in cubes, octahedrons, or intermediate forms. When the cube is deficient, its faces and angles belong, at least, to the first or monometric system of crystals; that is, they are derived from the cube. An aqueous solution of salt, however, exposed to a temperature of—10° C, deposits the salt in hexagonal plates, containing two equivalents of water, ($Na Cl. + 2 H_2O$); but as the temperature rises, the water of crystallization is expelled, and the crystals fall to pieces, being converted into a heap of minute cubes. Common salt has no combined water. Manufactured salt has generally the appearance of an irregular, hollow, four-sided pyramid, lined with steppes. Regnault explains this as follows:—Evaporation of brine takes place at the surface, and consequently crystal formation. The minute crystals, when first formed, are retained at the surface by capillary attraction. Other crystals deposit at their upper free edges, and on these again others in the same way, forming a hollow pyramid reversed, the apex pointing down. When

such weight is attained that capillary attraction and inertia are overcome, the crystals fall to the bottom.

Temperature has a great effect upon crystal formation. The force in virtue of which crystals group themselves, varies with the temperature, in nature and intensity, so that crystals of a given substance crystallize in different forms and even in different systems. Those which are formed at a high, or low temperature, are incapable of being preserved at an ordinary one; they become opaque, crumble, and reform, as in the case of sodium chloride crystallized at—10°C. This is an example of the dimorphism of common salt. Other more soluble salts, if present in solutions from which sodium chloride is separating, interfere very much with its crystallization. Buchan says, that a hygroscopic salt, such as magnesium chloride, or iron di-chloride, renders salt crystals transparent.

If a concentrated solution of common salt be exposed at a temperature of about 50° F., fine crystals, often an inch or more in length, may be obtained. In a cold atmosphere they effloresce; but with heat they liquefy in the water of crystallization.

Again, length of time, and the state of rest or motion, have a most important bearing on the crystallization of common salt. For the formation of perfect cubes, salt requires both a considerable interval of time, and undisturbed repose. Lieut. Lynch, of the United States Expedition, in the year 1848, found perfect cubes of salt on the bottom of the Dead Sea, at a depth of about 1,000 feet.

The growth of a crystal in a salt solution is affected by its position. As it can only receive fresh increments of salt on its exposed surfaces, these develope, whilst the face on which it rests, remains stationary. The upper face, which receives the salt falling from the surface, where it is sepa-

rated by evaporation, grows more rapidly than the sides; hence the crystal developes like a pyramid reversed, the broad base being uppermost. By altering the position of the crystal, from time to time, its shape can be controlled. If all its faces are exposed equally, and for equal lengths of time, to fresh deposits, it grows as a regular cube.

Urea in small quantities modifies the crystal form of common salt, making it crystallize in octahedra.

E. Beram, (Chem. News, vol. xxxv, p. 17), mentions that he dissolved some sodium chloride in hydrochloric acid. This solution deposited on cooling, long, needle-like crystals, composed of 94·40 per cent. sodium chloride, 5·48 per cent. water, and slight traces of hydrochloric acid. After a time these crystals broke up into ordinary salt cubes.

It is not generally known that salt forms durable stalactites; soft ones, that break up on handling, are common around the edges of salt boilers. Some very fine salt stalactites, 2 feet in length, and yielding a metallic ring, were found by the author, hanging from the lower opening of an abandoned shaft, in the Marston Mine. All salt stalactites are hollow. This is because the first drop of brine, as it hangs, crystallizes at the surface, by evaporation; but the pressure of brine above it, causes the centric fluid to drip out at the bottom, leaving a shell of salt attached to the rock. Fresh brine, flowing over the shell, increases its thickness, by deposition; but the terminal drop continues the hollow formation. Salt stalactites are also nodular and irregular, owing to differences of deposition caused by air currents. There are very fine salt stalactite caves in Westphalia.

Dr. Warth has found in the Sujewal and Purwalla Mines of the Punjaub, beautiful long, curving, fibrous, spun-glass-like crystals of salt. It is noticed that in these mines the

salt crystals often assume unusual forms, the margins of the cube faces being replaced, so that the solid angles have six bevilled edges. Salt crystals formed at low temperatures, especially when unduly hurried, or in a moving fluid, contain hollows or spaces filled with air, fluid, or foreign matter, mechanically enclosed; these from their common parallel arrangement, are believed to have arisen during the deposition of the successive planes of growth of the crystal. Manufactured salt crystals are almost always of this kind. It is the cause of the opacity of the salt. Dumas found that some rock salt from the Wieliczka Mine, in Poland, *decrepitated when dissolved in water*, disengaging bubbles of marsh gas—a hydrogen carbide. The force of these little explosions was so great, when large bubbles escaped, that the tumbler, used in the experiment, was shaken. The gas is probably derived from the decomposition of organic matter contained in the brine. Dumas noticed that the salt was nebulous in direct proportion to the gas it contained. (Revue Encyc. v. 66, p. 45). According to Nicol, Cheshire rock salt, also, contains small cavities, partly filled with air, and partly with a concentrated solution of magnesium chloride and some calcium chloride. T. Sterry Hunt believes that the presence of calcium chloride indicates a primordial sea, rich in that salt. We shall see hereafter that Cheshire rock salt contains large hollows, filled with inflammable gas. The phenomenon of decrepitation on heating which is caused by the expansion of the gas, or fluid, and bursting of its envelope, attests the existence of pores, even in the minute particles of well-ground table salt. The nature of the substance enclosed in the crystal is a matter of great practical interest to the geologist; and probably also to the consumer. At Wieliczka a curious phenomen has been noticed in the cavities of

salt crystals viewed under the microscope. A bubble appears to fall about, from one point to another, as the position of the crystal is changed; just as a solid ball would roll about in an empty glass. Salt sections, mounted on slides, for the microscope, showing this singular property, are obtainable at Wieliczka.

Cleavage.—Rock salt has perfect cubical cleavage; that is to say, it splits up, readily, in planes parallel to the faces of the cubes of which it is composed; an important point to bear in mind, in mining operations.

Pseudomorphs.—A mineral which retains the form and outward appearance of another, whose substance it has gradually replaced by chemical action, is called a pseudomorph. It is stated in Jukes and Geikie's Manual of Geology that "common salt occurs as a pseudomorph of anhydrite and gypsum. Gypsum and polyhalite also occur in the form of salt. But the most curious and important pseudomorph of salt is one in the form of dolomite, (magnesian limestone.) Of the pseudomorphs of other minerals in the shape of salt, the most interesting are limestone and sandstone. The replacement of salt by limestone appears not to have been confined to single crystals, but to have extended to whole beds." In the Mayo Salt Mines, in the North of India, beds of pseudomorphs of salt crystals are found on the under surface of the upper green sandstone. Dr. Warth, Chemical Analyst of the mines, in the Inland Customs Report for 1869-70, explains their formation as follows:—" On a flat shore covered with a layer of freshly deposited mud, after the evaporation of the salt water, the resulting salt crystals were formed in the mud, in such a way, that half of their surface was exposed and the other half lay buried. Further evaporation caused the mud to harden. After this had happened, the level of the sea water

again rose, and the tide flowing over this hardened mud dissolved the crystals, bringing sand, which was deposited in a thin layer over the mud. This sand also entered into the spaces left by the dissolved crystals, forming casts of them. Other layers of mud and sand settled upon the first ones, and the same process of crystallization may have been repeated or not. In the hardened state in which we now find the layer—the mud as marl, the sand in the form of sandstone slabs—the casts of the crystals are all found as they ought to be found, *i.e.*, on the lower side of the sandstone slabs. They appear when the marl is washed away by the rain. Some crystals are very beautiful and show that pyramidal form which is so characteristic of salt produced by evaporation."

Perimorphism appears to be the correct explanation of a remark in the Bible which has puzzled many commentators. "Salt is good, but if the salt has lost its savour, wherewith will ye season it," (St. Mark, ix, 50.) Salt in contact with lime, is under certain circumstances, replaced by sodium carbonate, whilst calcium chloride drains away. Soda is found, in the salt region of Aleppo and many other places, which has formed in this way. There is reason to suppose, also, that salt may be acted upon by the carbonic acid of the atmosphere and converted into soda. Maundrell, in "the valley of salt, Gebul," mentions that he broke a piece which had been exposed to the sun and air, which had lost its taste at the surface, though not its crystalline form, and still retained its salt taste in the interior. Pliny also speaks of salt loosing its flavour. It is a common thing to find a network of the prismatic crystals of sodium carbonate, efflorescing on the mortar of buildings, near the sea; especially if brackish water has been used to slake the

lime. Here also common salt is converted into soda, as the result of the reaction of salt and lime.

Perimorphism.—At the Sambhur lake, in the North of India, where salt is manufactured from brine by solar evaporation, and the daily range of temperature is wide, crystals of sodium sulphate are formed in the salt-pans in the cold mornings. As the sun rises and the temperature increases, these crystals no longer form, but minute crystals of sodium chloride are deposited in delicate layers upon them. As the water further warms, sodium sulphate dissolves out of its new casing, leaving hollow casts of its prismatic crystals formed of common salt. This is an instance of the *perimorphism* of common salt. If these casts were filled up with a further deposit of sodium chloride, they would then be true pseudomorphs.

Endomorphs.—A mineral enclosed within another is termed an endomorph. Many minerals, in fact most of those known to be associated with common salt, as gypsum, anhydrite, fluorspar, copper pyrites, bitumen, &c., occur enclosed in salt. Nearly all the minerals mentioned in the following chapter are found now and then as endomorphs in rock salt.

CHAPTER III.

ASSOCIATED MINERALS.

Common salt, in mines, and surface deposits, has, occasionally, largely associated with it, a number of other salts, about which it is necessary to know something. In a general way they are all derived from the sea, from whence also came the salt; gypsum, magnesium and sodium sulphate, are the most common.—According to Jukes and Geikie's Manual, "Salt is generally associated with anhydrite and gypsum, sandstone and carbonate of lime. Other salts also occur associated with it, such as polyhalite, a heteromeric compound of calcic, magnesic, and potassic sulphates. At Stassfurth in Prussia, it is associated with compact boracite and magnesic sulphate, one molecule of which, with about ten of common salt, form a heteromeric mineral called martinsite. The association of boracite is interesting, because in the Asiatic steppes borax lakes appear to occur in the district of the saline lakes. In the salt lakes, about the mouth of the Volga, a compound of sulphate of soda and sulphate of magnesia, called *astrakanite,* is formed in winter; a similar mineral, called *bloedite,* is found in some salt beds. At Villa Rubia in Spain, glauberite, a compound of the anhydrous sulphates of lime and soda, occurs in the salt. The bloedite indicates, perhaps, a low temperature, and the glauberite a high temperature, during the deposition of the salt."

At Aschersleferr, near Stassfurth, in Prussia, large deposits of valuable minerals were brought to light in 1877, whilst sinking speculative borings to ascertain the extent of the Stassfurth salt deposit. These were found in the dip formed by the three towns, Magdeburg, Halle, and Nordhausen, and are supposed to be the residue of an inland sea. The borings passed through salt clay first, and then struck a species of salt called *kieserite,* containing 19 per cent. potassium chloride; next *carnalite* ($KCl\ MgCl_2 + 6\ H_2O$), and *kainite* ($K_2\ SO_4$, $MgSO_4\ MgCl_2 + 6\ H_2\ O$), were found. Below these *kieserite* ($MgSO_4 + H_2\ O$) monohydrated, was found in great abundance, equal to about 17 per cent. of the whole deposit. *Polyhalite* ($2\ CaSO_4$, $MgSO_4\ K_2\ SO_4 + 2\ H_2O$) was found in two layers, one above the *kieserite* and one below the common salt. Rock salt was found underlying the other deposits to a depth of 2,000 feet, unexhausted. In the *carnalite* and *kieserite* were *sylvin,* nearly pure potassium chloride, *trachydrite,* ($CaCl_2\ 2\ MgCl_2 + 12\ H_2O$), *astrakanite* + $4\ H_2O$, and boracite ($2\ Mg\ 3\ B_8\ O_{15}\ MgCl_2$). Such quantities of sodium sulphate are now obtained from the Stassfurth salt deposit, that the manufacture of the sulphate from sea water, on the Mediterranean coast, has been abandoned in consequence. The order of deposition of the salts, the most soluble on the surface, and the rock salt beneath, prove their formation from a sea like our own.

In the "Mayo" Mines, salt is associated with variously coloured clays, white, pink, red, violet, etc., with *selenite,* variegated gypsum beds, limestone, calcium chloride, magnesium chloride, magnesium sulphate, etc. Dr. Warth makes a statement worthy of note, viz., that at the "Mayo" Mines, bad salt is associated with magnesium sulphate, and good

salt with calcium chloride. He also speaks of *brogmartite,* a combination of calcium and sodium sulphates. Two allied minerals, compounded of potassium and magnesium sulphates, and potassium and sodium chlorides, also occur with the salt. These valuable potassium salts are found in considerable quantities at the base of one of the salt seams. The sulphates are grey, the chlorides red in colour. Their analyses are given, as follows, in the Inland Customs Report, 1872-73 :—

	Red Mineral.	Grey Mineral.
Potassium chloride	61·43	3·80
Sodium "	29·32	......
Magnesium sulphate ...	7·78	58·02
Potassium " ...	......	38·00
Water	2·10	0·62
	100·63	100·44

In the Mari salt hills, transparent, reddish, bi-pyramidal, quartz crystals, are found in large quantities. They are known locally as Mari diamonds from their great beauty and regularity.

The form and colour of the salts most commonly associated with common salt, are here given, to enable the miner to apply a rough test, which will help him to distinguish one from the other.

$MgSO_4 + 7H_2O$. Epsom salts, or magnesium sulphate, crystals derived from a right rhombic prism. $Na_2 SO_4 + 10H_2 O$. Sodium sulphate, or Glauber's salts, crystals derived from an oblique rhombic prism. $CaSO_4$. "Anhydrite," calcium sulphate, trimetric, rhombic or sometimes lamellar. $CaSO_4 + 2 H_2 O$, Gypsum, calcium sulphate. monoclinic prisms, laminar, lamellar or fibrous pieces. $Na_2 Mg (SO_4) + 6H_2 O$. "Astrakanite," a double sulphate of sodium and magnesium, monoclinic or trimetric. $MgK_2 (SO_4)_2 + 6H_2 O$. Double sulphate of magnesium and potassium, trimetric, rhombic

or right prismatic. $CaNa_2(SO_4)_2$. "Glauberite," a double sulphate of calcium and sodium, monoclinic or oblique prismatic. $CaCO_3$. (Formed below 90° F.) "Aragonite," right rhombic prism. $CaCO_3$. (Formed above 90° F.) "Calc spar," rhombohedral, or scalenohedral Fe_2O_3. Sesqui oxide of iron—"Hematite," hexagonal or amorphous, red in colour. FeS_2. Disulphide of iron—Pyrites, cubes, monometric system, orange colour. Some of these, as *astrakanite*, gypsum, calc spar, and Glauber's salts, are formed at low temperatures; others, as *glauberite*, *anhydrite*, and *aragonite*, indicate a high temperature. Ferric disulphide, Ebelmann says, is daily formed whenever organic matter in decomposition acts on the sulphates of minerals, or sea water, in the presence of ferruginous mud.

Bitumen is also pretty frequently associated with common salt, both in mines, and in the neighbourhood of natural brine springs. It is found in lumps called *Hajar Mousa*, or Moses' Stone, on the borders of the Dead Sea.

In the eastern part of the *trans indus* salt region, much of the upper crust of salt is bituminous, and layers of bituminous clay are found in the body of the rock salt. In Burmah, salt and petroleum springs are found occurring together. Karsten says, that at Marmarosh, in Hungary, rock salt is covered by bituminous clay. Salt springs exist in the region of earth oil, and naphtha, at Baku on the Caspian Sea. In the United States salt is associated with coal. In the volcanic region which occupies the interior of Java, brine springs are associated with naphtha and petroleum springs. Captain Burton found sulphur beds associated with rock salt in the land of Midian.

In some parts of China, salt springs are associated with springs of mineral oil. In Durham, salt is associated with coal formations. In the Chinese provinces of Young Hian and Wei Yuan Hian, salt springs alternate with springs of mineral oil and inflammable gas, resulting from the decomposition of coal. The inflammable gas is so plentiful and

constant that it is used by the Chinese in the manufacture of the salt, which is obtained from these springs by evaporation. The salt springs are obtained by boring, and it is stated in " The Bibliothéque Universelle" that if a light be applied to the mouth of the tube in which the brine is ascending, a jet of flame, from 20 to 30 feet high, is thrown up. The salt water is evaporated in kettles. A single well supplies gas enough to heat 300 kettles; the excess of gas is conducted beyond the salt works, and there burnt off as waste.

At the Meeting of the Pharmaceutical Society of London, 1st March, 1877, it was stated that the particular source from which the borax of commerce is now obtained, is a salt lake near the Colorado river, in California. This lake, about fifteen miles long and eight broad, is now dry and occupied by beds of common salt, sodium sulphate, borate of soda, and blue mud: borate of lime was also present in small quantities.

M. Dieulafait, who has specially studied the origin and mode of formation of boric acid deposits in the Lagoons of Tuscany, and in analogous beds, considers that boric acid is a sedimentary deposit of salt marshes, and that it is not the result of volcanic action. Boric acid has always existed in sea water, and has been deposited whenever suitable conditions have occurred, as in the Trias, and certain periods of the Tertiary formation. It forms one of the last constituents of the mother liquor of salt marshes. (Academy of Science, October, 1877).

At Kalabagah, in Northern India, large alum and salt-petre factories were formerly worked in the salt range. Coal, sulphur, and petroleum, were found in the same neighbourhood.

With reference to the large quantity of magnesium chloride occasionally found in salt lakes, M. Cloez states that he has produced carbonate of soda artificially, by the

action of carbonate of magnesia on sodium chloride. He thinks that this phenomenon may occur in nature, explaining the natural occurrence of "natron," as well as the magnesium chloride of the lakes. The reaction with bicarbonate of magnesia has long been known. It would explain the presence of natron in dolomitic districts ; but it is more often produced by the reaction of salt with lime, owing to the greater distribution of lime salts. This is a point that will be noticed hereafter, in treating of the agricultural chemistry of common salt.

Of all the salts associated with common salt, gypsum is by far the most prominent. Karsten says that the North American Indians look upon gypsum and rock salt as being simply altered conditions of the same rock. The Afghans call salt "The brother of gypsum."

Chemical Analysis.—For the benefit of those who may be thrown upon their own resources for the analysis of salt specimens, I here give a rough method of salt analysis, which requires very little previous Chemical training for its execution. We have seen that the salts with which common salt is associated in the dry state, are the same as those found with it, dissolved in the sea. Whether we examine sea salt, brine springs, salt lakes, earth salt, or rock salt, these are the salts to be expected.

For all ordinary purposes, therefore, it is enough to ascertain in a given sample, the quantity of sodium chloride, insoluble residue, organic matter, magnesium chloride, magnesium sulphate, calcium sulphate, and perhaps calcium chloride. In solid samples, the amount of moisture should first be determined.

Moisture.—Weigh 100 grains of the salt, ground to a fine powder; place it in a crucible, which rest on sand, within another crucible, to avoid decrepitation; then heat over a

gas or spirit lamp, keeping the salt for a few minutes at a moderately high temperature—re-weigh, and note down loss of weight as moisture. From this calculate percentage of moisture by simple proportion.

Insoluble residue.—If a solid sample, dissolve 100 grains in sufficient distilled water; filter through a weighed filter paper; dry the paper carefully; re-weigh and note excess of weight as insoluble residue—sand, etc.: calculate percentage. If a liquid, use a weighed quantity of it, as 1,000 grains, filter, and calculate as above.

Organic matter.—Take the filtering paper used in last process, which holds the insoluble matter, and burn it; re-weigh the ash and note the loss of weight as organic matter burnt off. A correction should be made for loss of organic matter of filter—this can be found by burning a filter paper of equal weight.

Sulphuric Acid.—Dissolve 100 grains of the salt, or take 1,000 grains of the brine. Filter it, add hydrochloric acid until an acid re-action is given with litmus test paper, then add barium chloride in solution, in excess, and let it stand for 24 hours. Collect the precipitate on a tared filter; dry it; re-weigh it, and note excess weight as barium sulphate. Taking excess weight as x, $\frac{x \times 96}{233}$ = sulphuric acid radicle, SO_4.

Calcium.—Take fresh weights as before—make the solution basic with a few drops of solution of ammonia and of chloride of ammonium, add plenty of oxalate of ammonia, and let it precipitate for 24 hours. Collect the precipitate on a tared filter and calcine it for 15 minutes, at a red heat, in a weighed crucible. Re-weigh the crucible with calcined filter, and note excess of weight, minus known weight of filter ash, as calcium carbonate. Let x be the weight of calcium carbonate; then, $\frac{x \times 2}{5}$ = calcium.

Magnesium.—Use the water from which calcium has been precipitated in last test, and re-weigh it for subsequent percentage calculation. Add solution of ammonia, for basic re-action, and then sodium phosphate in solution, liberally; let it stand and precipitate for 24 hours. Little needles of the triple phosphate form. Collect on tared filter and calcine as in last test, but for a longer time and with a greater heat, to reduce the triple to the pyrophosphate. Re-weigh crucible and note, as in last case, excess. Excess equals magnesium pyrophosphate = X. $\frac{X \times 8}{37}$ = magnesium.

Chlorine.—By the volumetric method. First prepare a solution of 16·997 grammes (= 262·2 grains) in a litre (= 1·760 pints) of distilled water. Of this solution 1 cubic centimetre equals 0·00355 of chlorine—keep this in a burette. Add enough chromate of potash to the solution to be tested to give it a yellow colour. If either solution be acid, add a little sodium carbonate. Now drop in the caustic solution from the burette, and keep stirring until the brine acquires a permanent red tint. Deduct 0·1 CC. for tint, and multiply the remaining CC., used, by the co-efficient of chlorine = chlorine in grammes per litre. Multiply by 70 to bring to grains per gallon. As there are 70,000 grains in a gallon, the percentage can be calculated.

Combination.—Having found by the above processes the quantities of chlorine, calcium, magnesium, and sulphuric radicle (SO_4), and calculated the percentage of each in a given weight, the next step is to combine them according to their equivalents, which are as follows:—

	Equivalent.
Sulphuric radicle	96·
Chlorine	35·5
Calcium	40·
esium	24·

Sodium, equivalent 23, is not mentioned here, as practically it is not required. All the chlorine left, after combining the foregoing elements, is written down as sodium chloride.

These molecules are to be arranged into salts as follows. Begin by combining calcium and sulphuric radicle, as calcium sulphate. If a balance of sulphuric radicle remains over, combine it with magnesium and form magnesium sulphate.

If on the contrary a balance of calcium remains, combine it with chlorine, taking two atoms of chlorine for each one of calcium, as the latter is a dyad metal, and show it as calcium chloride $Ca.Cl_2$.

If any magnesium remains over, combine it with chlorine, using two atoms of chlorine for each of magnesium, as the latter is a dyad, and show it as magnesium chloride. The remaining atoms of chlorine combine with sodium and show as sodium chloride.

An illustration showing how the elements should be combined will facilitate the comprehension of this part of the subject, especially to a beginner. Suppose, for example, that the parts per cent. found, stood as follows:—

Sulphuric radicle, SO_4	= 2·0	Magnesium	= 1·0
Calcium	·25	Chlorine ...	= 4·5

Required the number of molecules of SO_4 to combine with ·25 of calcium. As the equivalent of calcium 40, is to the equivalent of SO_4 96, so will ·25 be to the answer. $\frac{96 \times \cdot 25}{40} = \cdot 60$. Note down calcium sulphate = ·85 ($CaSO_4$.) Deduct the ·60 of sulphuric radicle used, from the whole quantity, 2·0, of SO_4, found, and as the balance, 1·40, is not enough to combine with all the magnesium, make the following proportion. As the equivalent of SO_4, 96, is to that of Mg, 24, so will the balance, 1·40, be to the quantity it

will combine with $\frac{24 \times 1{\cdot}40}{96} = {\cdot}35$. Combine with 1·40 and write down magnesium sulphate = 1·75 (M.) This leaves a balance of magnesium = ·65. Com this with two equivalents of chlorine to form magnesium chloride, as follows: As 24 (the equivalent of magnesium) is to 71, (two equivalents of chlorine) so will be the ·65 of magnesium remaining, to the answer, viz., 1·92 chlorine. Adding this to the remaining magnesium we get magnesium chloride = 2·57. Deduct the chlorine used in last calculation, viz., 1·92, from 4·5, the whole amount of chlorine found, and combine the final balance, 2·58, with sodium as sodium chloride. Thus, as 35·5 (the equivalent of chlorine) is to 23 (the equivalent of sodium) so will be 2·58, to the amount of sodium that will combine with it, viz., 1·67. Adding this to 2·58, chlorine, we get sodium chloride 4·25. We then have in parts per cent. and per mille.

Calcium sulphate	= ·85	8·50
Magnesium sulphate......	= 1·75	17·50
Magnesium chloride......	= 2·57	25·70
Sodium chloride	= 4·25	42·50

Specific Gravity.—The specific gravity, or density of the brine compared with an equal bulk of distilled water, valued at 1,000, should invariably be noted; and for purposes of comparison, this observation should be made at the temperature of 60° Fahrenheit, or reduced to that, by calculation.

The specific gravity of solid salt should also be given when possible. A cubic foot of distilled water at 60° Fr. weighs 1,000 ounces (62 lbs. 8 oz.). With its acknowledged sp. gr. of 2·, a cubic foot of sodium chloride should weigh double that. The Foreman of the Marston Mine, who knew nothing about the scientific requirements of the case, informed me that a cubic yard of their rock salt averaged 1½ tons. This is exactly 124·44 lbs. per cubic foot. Rock

salt from the "Mayo" Mines weighs about 93 lbs. to the cubic foot, according to Dr. Warth; but his sample may have been bad measure, or of inferior quality. As regards artificially formed, or manufactured salt, the relation between cubic feet and lbs. is very variable, it depends naturally on the size, shape, weight, and percentage, of moisture, air, foreign salts, insoluble matter, etc., contained in the crystals. Practically; well formed dry bay salt, should not weigh less than 60 lbs. to the cubic foot. Much Indian sea salt, however, falls below that.

Note.—When weighing salt, weigh it always in the dry state and dry it carefully. All re-weighments, after drying, should be made as quickly as possible, as the magnesium chloride, usually present in the sample, re-absorbs moisture from the atmosphere with great rapidity.

Mass and density.—If the sample under examination is an ordinary sample of large grained sea salt, take a *measured* quantity of it, of known weight, and triturate it to a fine powder in a mortar, to expose its interstitial water to the drying process; now dry it as described in para. 4, page 50, re-weigh it and *re-measure* it. The loss of bulk is a measure of the percentage of sodium chloride *to bulk,* in the original sample, that is of its density. Thus, the author having treated 200 CC. of Indian salt in this way reduced it to 116 CC., loss 84 CC.; equal to 42 per cent. If for example, we call the density of crystal rock salt 1,000, and finely ground salt tightly packed 500; the density of such Indian salt would only be 290, or about a quarter that of solid salt, an important matter, to bear in mind, where, as in India, salt is sold by the Government monopoly, by weight, and retailed by the dealers to the people, by measure.

Roughly, the amount of salt in solution is found by the addition of nitrate of silver to the water to be tested. It is found that 15 milligrams of salt per litre, produce a white cloud on the addition of the caustic solution. Six centigrams cause decided turbidity; whilst a considerable precipitate will be formed with 0·140 grams. The white precipitate is caused by the formation of silver chloride which is insoluble in water. It is well to acidulate the water to be tested with dilute nitric acid, before adding the silver salt.

CHAPTER IV.

THE SALT SEA.

Our knowledge of the exact dimensions of the ocean is made up of many hypotheses and few measurements, and is not quite as accurate as could be desired. Professor Mosely, F.R.S., in a lecture on the Deep Sea, delivered at the Royal Institution, 5th March 1880, estimates that four elevenths or nearly three quarters of the earth's surface, is covered by the sea: that it fills a cubic space twenty-two and a half times greater than that of the land, above sea level; and that if the whole land, now above water, were washed into the sea, and uniformly spread out, it would form a deposit five hundred feet thick. These are useful illustration of the enormous extent of the sea.

The sea varies in depth a great deal in different parts. The greatest depth found, 4,655 fathoms, or about five and a quarter miles, was got by the Tuscarora, of the U. S. Navy. Maury estimates the average depth of the ocean at about two miles. Mr. Otto Krommel, who is a great authority, estimates it at 1,877 fathoms, or over two miles.

The cubical contents of the sea is variously estimated. For instance, Sir C. W. Thomson, Challenger's Report, estimates the area of the great ocean basin at one hundred millions of square miles: this with an average depth of two miles, as above noted, would give 200,000,000 cubic miles, as the volume of the ocean. His estimate however of the average depth is even greater than 2,000 fathoms. Herschel, many years ago, calculated that the weight of the ocean was 2,494,500 billions of tons. As the average weight

of a cubic foot of sea water, sp. gr. 1,027, at 60° F., is 1024·5, or say 1,025 ounces, it is easy to calculate that this would give an ocean 589,784 cubic miles in extent, which is apparently very much under the mark. Mr. Crole has pointed out that the ocean spread is so great that, notwithstanding its great depth in some parts, it resembles a sheet of water one hundred yards in diameter and only one inch in depth. This is a rough relative estimate; but taking it as the basis of a calculation, and substituting miles as we are entitled to, we get 25,920,000 cubic miles. Mr. Otto Krommel, whose researches into this question are recent, and whose opinion carries weight, places the volume of the entire sea at 3,138,000 cubic miles.

It is considered certain by astronomers and geologists, that in the earliest Azoic period of creation, the temperature of the earth was so high that it formed a molten mass, and all volatile bodies, or those capable of being converted into vapor at high temperatures, surrounded the globe as an atmosphere; that the dense ocean literally boiled, and superheated steam mixed with the other atmospheric vapors. We may imagine sodium and chlorine to have existed in the gaseous state at this period. There can be little doubt about sodium having so existed, since by the aid of the spectroscope we see it in the atmosphere of the sun and those stars, as Aldabaran and Betelgeux, which have been carefully examined. There is some doubt about chlorine, since it hardly exists, as such, at higher temperatures than 800° C. The recent experiments of Victor and Carl Meyer, of Zurich, show that it diminishes in density up to 1,200° C., at which point it is about 1·62, and increases in volume one-half, becoming aleotropic. Be that as it may, however, with the gradual fall of temperature, sodium chloride would form, and deposit upon the surface of the land and water: and as the cooling

process continued, the aqueous vapor would condense and fall upon the earth in the shape of hot rain.

This rain would condense at a much higher temperature than that at which water boils at present. All the water now on the surface of the earth must then have existed in the state of vapor. Mosely estimates that if the surface of the globe were uniformly level, the sea would cover it to a depth of one thousand fathoms. This mass of water converted into vapor would produce a pressure of 204·74 atmospheres, or over one ton to the square inch. To this must be added the pressure of other gases then existing. Mallet thinks that watery vapor may have condensed at the temperature of molten cast iron. This water, charged with acid gases, would have a powerful disintegrating and solvent action on rocks. The rainfall, moreover, was not limited to one thousand fathoms, or according to our present "rain guage" standard, 72,000 inches. It was several times greater, as the same water would have been vaporised and again precipitated, repeatedly, through variations of temperature and pressure. It would come in contact with surface deposits of sodium chloride and other salts, which, volatilizing at a low red heat, had previously been deposited on the top of the less volatile rocks forming the earth's crust. All the soluble salts on the face of the earth, except those protected by insoluble coverings, would then be washed into the sea. Hence, we can only conceive of the primordial sea, as being literally charged with salts of all kinds.

In process of time—and who can say how long—this seething, turbid sea, settled down, and was relieved of its superfluous solids by subsidence, supersaturation, deposition, and chemical changes of various kinds, involving the formation of insoluble salts. Roughly speaking it may be said that nearly all the stratified rocks, and many of the so-called

granites, have been formed in the sea by deposition of solids separated from its brine.

The late Azoic period was pre-eminently a period of deposition, as far as the sea was concerned; surrounded by primitive igneous rocks, washed bare of soluble salts, it received comparatively little fresh solid matter, and had time to dispose of the solid materials with which it was overloaded.

At length the sea became fitted for the reception of living creatures, and entered upon its second or palæozoic stage. This took place some time about the Pre-Silurian era, as is evident from the vestiges of early life found in the deposits of that period. It is commonly believed that the palæozoic sea differed very little from the modern ocean. T. Sterry Hunt, however, who has traced (Chemical and Geological Essays) the action of the causes which have modified the original azoic brine, believes, that the palæozoic sea was richer in calcium chloride and magnesium salts, and poorer in common salt than the present sea. He refers to "fossil sea waters which are still to be found in certain regions, imprisoned in the pores of the older stratified rocks," and instances certain Canadian and other brine springs, from the Upper Silurian, having the chemical composition referred to. The absence of calcium chloride from the modern sea is explained by the action of the alkaline carbonates in breaking it up into calcite, which is precipitated, and magnesium and sodium chlorides, which remain. However this may be, as regards the palæozoic sea, it indicates a source of origin of common salt which has been at work in nature's laboratory, more or less, since the azoic period, and which still continues. The sodium carbonate resulting from the decomposition of feldspathic rocks, brought into the sea, by rivers, is converted into common salt, by the action of

calcium chloride. This source of formation of sodium chloride is now well nigh extinct, since but little calcium chloride is left in the sea.

It is an interesting question, how far the density of the sea has been influenced by the separation from it of the vast masses of salt contained in rock salt formations? Let us endeavour to estimate the amount. There are not sufficient data available to form an accurate estimate even as to the quantity of rock salt at present *known* to exist, but some idea may be formed on the subject by a passing glance at some of its principal formations. The most extensive mines in the world are those found on the continent of Europe, extending for 500 miles along the Carpathian mountains, stretching out laterally for 100 miles, and having a thickness in some places of 1,200 feet. In neighbouring Poland, the Wieliczka Salt Mine is the largest known. It has been worked for the last 629 years. Some of its galleries stretch for 40 miles, and yet the resources of the mine have scarcely been touched. The area occupied by the Trans-Indus, or Afghan salt region is about 1,000 square miles; and it is estimated that about one-fifth of the entire area is taken up by salt, which frequently occurs in marked exposures. In one place, for a stretch of four miles, the rock salt forms bold cliffs, rising to 200 feet, on either side of the banks of a stream. The bottom of this salt deposit is unknown. Mr. Wynne, of the Geological Survey, estimates its thickness, in parts, at 1,200 feet. The same authority estimates the Cis-Indus, or Indian, salt range, as extending 134 miles in length by about 5 miles in breadth, comprising an area of about 676 square miles. The salt zones in this region have a thickness ranging from 100 to 275 feet. In England a large bed of rock salt lies beneath the valley of Cheshire, from Malpas to Con-

gleton. There are about 25 pits now open in this region, of which seven are at Marston, and six at Winsford. About 40 old workings are closed. The Northwich Mine has been at work for 210 years. The two beds of rock salt in the Marston Mine are, each, about 90 feet in thickness. The Ontario salt region, which includes the Onandaga, is believed to extend to the boundaries of lake Huron. This is but a rough sketch of the quantity of rock salt in three or four of the best known salt regions. Taken in connection with the geographical distribution of rock salt, it enables us to form some idea of the enormous masses of rock salt which exist scattered over the globe, known, and unknown.

It would not be rash to estimate the unknown salt deposits as equal in bulk to those that are known, since much more than half the globe is covered with water and out of ken, and the mineral resources of the habitable portion are as yet imperfectly explored. This salt, if the view generally received regarding its formation be correct, was separated from the sea by deposition. We have no reason to suppose that the sea is either greater, or less, in volume, now, than it was in the Pre-Silurian period. On the contrary, geologists conclude that it remains the same. Dr. Warth has calculated the cubical salt contents of the "Mayo" Mines at 10 cubic miles. The area of the range is 670 square miles and the average depth of the salt deposit is about 200 feet. It varies according to Mr. Wynn from 100 to 275 feet. If the salt lay 200 feet thick all over this area, the cubical contents would be 26 cubic miles. The salt occupies more than one-third of the whole area. The area of the Trans-Indus salt range is 1,000 square miles. Mr. Wynn calculates that one-fifth of this region, or 200 square miles, is taken up with salt. The depth of the deposit

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varies, but it reaches in some places 1,200 feet: say that it averages 500, and we get a cubical contents of 20 cubic miles of rock salt. The Carpathian salt region occupies an area of 50,000 square miles. The salt, to judge by the map, which shows salt mines at wide intervals, would occupy about one-fifteenth of this area, or 3,333 square miles. Its depth in some places is very great, over 1,200 feet; it may be assumed to average 600 feet in thickness; this would give us 416 cubic miles of rock salt. The English salt-bearing region occupies about 450 square miles. Taking one-third of it as salt deposit, with an average thickness of 100 feet, we get about 3 cubic miles of salt. There remain the Spanish, Irish, French, Swiss, North American, Bolivian, Peruvian, Mexican, African, Chinese, Burman, and Asiatic Russian salt deposits, the cubical contents of which I have no means of estimating, but, judging from analogy and general report, they may contain, on an average one or two cubic miles of salt, as they are local and comparatively insignificant beds; say, at the outside, 41 cubic miles for all. We thus get 500 cubic miles of rock salt, arranged as follows:—

Deposits.	Cubic miles.
Cis-Indus	10
Trans-Indus	20
Carpathian...	416
English	3
All others	41

Doubling this for the sake of all undiscovered rock salt deposits in the earth, whether above or below the bed of the sea, we get a total of 1,000 cubic miles of rock salt. My own impression is that this calculation errs very much on the side of excess; that there is not so much as 1,000 cubic miles of rock salt formation extant.

If we now take Krummel's estimate of the volume of the sea, which is a low estimate compared with others—we can

find how much salt is left in the sea, and compare its present with its former condition. For this purpose I have adopted Schweitzer's analysis of the English Channel, which shows 2·70 per cent. of common salt.

To make use of Krummel's cubic miles, we must have the quantity of salt in a cubic measure of our sea water, having the specific gravity 1·027. It so happens that a cubic foot of distilled water, weighs at 60° F., 997·6 ounces. At the same temperature and pressure a cubic foot of sea water, specific gravity 1·027, would weigh 1024·5 ounces. As we have seen that it contains 2·70 per cent., by weight, of common salt, we may calculate on 27·6 ounces of salt to the cubic foot of sea. Dr. Warth states that a cubic foot of "Mayo" Mine rock salt weighs 93 lbs. or 1,488 ounces. It would, therefore, require about 54 cubic feet of this sea, to yield a cubic foot of rock salt.

There are 147,197,952,000 cubic feet in a cubic mile. A cubic mile of the sea water would therefore yield 2,725,888,000 cubic feet of rock salt. If we multiply this by the number of cubic miles in the ocean and divide the resultant by the number of cubic feet in a mile, we get the number of cubic miles of rock salt in the sea. Krummel's researches show that the volume of the entire sea is 3,138,000 cubic miles. The number of marine surveys which have been made of late years would enable this calculation to be made with some approach to accuracy.

$$\frac{2{,}725{,}888{,}000 \times 3{,}138{,}000}{147{,}197{,}952{,}000} = 58{\cdot}111$$

We thus get 58·111 cubic miles of rock salt in the sea at the present time.

Supposing that 1,000 cubic miles of rock salt have been extracted from the sea, the loss from the original supply 58·111 + 1,000 cubic miles, is less than 2 per cent. But if we take higher estimates of the volume of the sea, such

as are in fashion at present, the loss becomes proportionately less. Schafhautl calculates the amount of salt in the sea at 305,342 cubic geographical miles. On this assumption its salinity has been diminished by the extraction of the above quantity of rock salt a little over ·3 per cent. For the sake of settling the question, as to the effect of this withdrawal of salt, upon the state of the ocean, let us assume that 2 per cent. of its original salt has gone out of it.

Now, this loss of 2 per cent. of the salt once held in the sea is almost inappreciable. The English Channel, according to Schweitzer, contains over 2·70 parts per cent. of salt. If all the salt in all the rock salt formations was restored again to the sea, the channel water would contain less than 2·76 per cent. of salt; that is, its increase of salinity would be represented by less than ·06 per cent. No one would be the wiser for it, not even the fishes.

But there is reason to suppose, that, for some thousands of years past—since the Tertiary period—a recuperative process, as regards the salinity of the sea, has been taking place. Rains and rivers have been washing the hills and valleys of the earth of their soluble salts, and large quantities of sodium chloride have been carried back to the ocean. It has been calculated that the River Mahanady, which discharges into the Bay of Bengal, near Cuttack, carries into it in solution, daily, about 3,000 tons of sodium chloride. Much of this salt is, doubtless, restored to the sea from the Silurian or Cis-Indus salt deposit, the very oldest known. This process has been going on for some thousands of years, so that the sea is probably now stronger in salts than it was in the Tertiary period, but the difference would be, in any case, trifling. The effect of salt manufacture over the world may be neglected, since "bay" salt obviously soon comes to form a surface deposit, which regains the sea within a few years.

From all this, it is evident that the palæozoic, as distinguished from the primordial sea, was hardly different in specific gravity, or salinity, from that which now exists, and that therefore the same species of plants and animals could flourish in it. This conclusion agrees with that arrived at by palæontologists working on a different line. They find the marine fossil fanna and flora of the very earliest times so little different from the primitive types now existing, that they conjecture them to have lived under marine conditions similar to those now obtaining. With regard to the salt restoration process, it may be interesting to note that a cubic mile of rock salt weighs 6,111,298,900 tons, taking the weight of a cubic foot at 93 lbs. Ten large rivers, such as the Mahanady, carrying off 3,000 tons a day, would require over six thousand years to dispose of one cubic mile. There is no immediate prospect of a rock salt famine; the "Mayo" Mine alone would keep the world in rock salt for 60,000 years.

The following analyses exhibit the chief saline constituents of the sea.

	Mediterranean.	English Channel.	Bay of Bengal.
Sodium Chloride	27·22	27·06	26·06
Magnesium "	6·14	3·66	2·81
Potassium "	......	0·76	1·20
Magnesium Sulphate	7·02	2·29	1·82
Calcium "	0·15	1·40	1·36
Magnesium Carbonate	0·11	......	......
Calcium "	0·09	0·03	......
Magnesium Bromide...	......	0·03	......
Carbonic Acid	0·20	......	......
Potash	0·01	......	......
Water	959·06	964·77	966·75
	1000·00	1000·00	1000·00
Analysts	Lament.	Schweitzer.	King.

It will be noticed that these widely separated seas are very much alike in chemical constitution. The water taken from the Bay of Bengal, for analysis, was procured from the beach, and was undoubtedly affected by fresh water drainage. It was, moreover, analysed only with reference to salt manufacture, and the salts noted, were alone tested for.

Besides the more important substances given in the above analysis, sea water contains a large number of elements in appreciable quantities. Thirty or more have been detected in it; and it is highly probable that all known bodies exist in it.

According to Forchhammer, appreciable quantities of manganese, ammonia, baryta, strontia, and silica, may be found in the sea. The latter mineral was contained in the proportion of ·03 per 10,000 parts in all the samples of sea water analysed. M. M. Marchand and Bunsen have both found lithia in sea water. The connection of boric acid with sea water, has been already noticed. M. Dieulafait says that by the colour it imparts to the hydrogen flame, this acid may be recognized in a drop of sea water weighing 0·0378 grams; and that the minimum quantity found in the Mediterranean is two decigrams per cubic metre of water. Dr. Wilson, some forty years ago, first pointed to the presence of fluorine in the sea. Phosphorous is contained in it in large quantities. The phosphorescent animalculœ, which illumine the sea at night, are constantly throwing off an oily secretion from their secreting gland, which is directly formed into phospho-carbon, by decomposition. M. Meunier has found minute proportions of arsenic in the sea. Hydrogen sulphide and hydro-sulphide of ammonia are formed in the sea by the decomposition of its sulphates in the presence of organic matter. Natural

sulphur is formed from the decomposition of hydrogen sulphide. Bromine is found in combination with sodium. Usiglio found 1·48 parts of sodium bromide in one hundred parts of Mediterranean salts; while ten analyses, by Von Bibra, from different seas, gave 0·86 to 1·46, in 100 parts. The sea contains less iodine than is popularly supposed. The researches of Sonstadt, published in the Chemical News (April and May, 1872,) show, that it exists as calcium iodate to the extent of one part in 250,000 of sea water. This compound is converted into iodides, by decaying organic matter, and again into iodine, which is set free, by the action of carbonic acid. It may be separated from the water by agitating it with bisulphide of carbon. This property of iodine and its compounds, of oxidising and being oxidised in turn, Sonstadt supposes to be concerned in the maintenance of the salubrity of ocean waters, by removing the products of organic decay.

The precious metals are also found in the sea. M. Meunier has made some investigations regarding its silver. He says that when sea water infiltrates a vein of galen—native sulphide of lead—all the silver is held and concentrated by the lead; as neutral sulphides brought into the presence of suitable metallic solutions, cause reduction of the dissolved metal. Sonstadt says that the sea water of the British Coast contains in solution about one grain of gold to the ton of water. Chloride of barium added to the water, throws it down, apparently as an aurate of baryta. It adheres to the precipitated sulphate, and yields by assay, an alloy of about six parts of gold to four of silver. It is kept in solution by iodine, liberated by the action already described. This would give one dollar of gold to 25 tons of sea water.

Bischof showed that the sea contains air and free car-

bonic acid gas: and experiments indicate that these gases are held in larger quantities, at some depth, than near the surface. Buchanan found 4·06 cubic centimetres of oxygen at a depth of 4·475 fathoms. M. Schlœsing—Nature, June 27, 1880—calculates that the sea holds in reserve, a quantity of carbonic acid gas, ten times greater than the whole quantity in the atmosphere. He believes that the atmospheric carbonic acid is regulated by that in the sea. This may be true in a certain sense, but the researches of Tornö, the Scandinavian naturalist, seem to show that the sea contains no free carbonic acid, but that it contains 5·3 mgs. per litre, as carbonates, and 44 grms. per litre as bicarbonates.

The specific gravity of the ocean is usually set down as 1,027. The surface density varies, however, in different parts, between 1024·6 and 1029: and the density, at different depths, varies in almost every part, within similar limits. It is entirely a question of dilution with fresh water. Where large rivers discharge into Gulfs or Bays, or land locked seas, the brine is comparatively weak. Where, on the other hand, the removal of fresh water by solar evaporation is greater than its supply by meteoric agencies—the brine is stronger than elsewhere. River mouths, or estuaries, are examples of the first kind. The Red Sea is perhaps the most notable example of the second kind. Hence, as a rule, coast waters are less dense than those of the open sea. The waters of the Mediterranean, Red Sea, Gulf Stream, and equatorial regions, have the highest specific gravity, as they suffer greater loss from evaporation than they gain by rainfall. Local areas, in shore, in the tropics, affected at intervals by changing meteoric conditions, present striking corresponding changes of density; but this, though a useful fact to bear in mind in the manufacture of bay salt,

does not affect the general question. The Polar seas are less dense than the wide ocean; it is supposed owing to the dissolution of enormous masses of glacier ice. Observations made by Dr. Moss in the Artic expedition of 1875-76 showed the specific gravity of the Artic Sea, to be 1024·67. Even the deepest parts from which samples were obtained showed dilution. It may be remarked that rain water sometimes lodges on the surface of the ocean, for a time, in calm weather. Ships have obtained a supply of comparatively fresh water from the surface of the sea, after heavy rain, by means of shallow scoops. Taking the density of the English Channel as 1—the Baltic is equal in density to 0·19; the Black Sea, 0·61; Irish Channel, 0·96; Mediterranean 1·11; Equatorial regions 1·12; North Atlantic 1·16; South Atlantic 1·20. It is stated that sea water in the Southern Hemisphere, generally, is stronger than it is in the Northern. The Antartic Polar belt, however, is the weakest portion of the whole sea, as it is the most encumbered with glacier ice.

It is very remarkable that the sea, which stretches from pole to pole, exposed to such widely different climatic and other local conditions, should present such uniform characteristics as it does. In point of fact, with the exception of the Polar Sea, in which the proportion of sulphates to chlorides is disturbed, the sea everywhere contains the same salts, and in the same relative proportions. Viewed on a large scale, it contains them, too, in scarcely different amounts. Herr Jacobsen analysed 46 samples of sea water, taken from the most different regions, and from different depths, and found that the amount of salts varied only between 0·312 parts and 0·220 parts per cent. The reason of this is, because, notwithstanding the geographical expressions which define it, the sea has no local limits. Its wide stretching arms embrace the earth and are in constant motion to and fro. Local causes

are powerless to stamp their peculiar features on the overwhelming movements of its vertical and horizontal currents.

There are four factors at work producing these movements or ocean currents, viz., difference of salinity, surface movements caused by wind, difference of temperature, and difference of level. Maury—in "The Physical Geography of the Sea"—draws attention to the formation of ocean currents by alterations of specific gravity. He considers this to be the chief source of motion. It has its origin in solar evaporation. In warm equatorial regions, evaporation proceeds at the rate of over half an inch a day. As watery vapour is liberated from the surface of the sea, the brine becomes denser than that beneath it, and sinks. Fresh brine is sucked in from cooler surrounding regions to supply its place; and this in its turn, acted upon by evaporation, becomes heavy, sinks, and causes an in-flow of other fresh brine. In the meanwhile, the dense brine beneath is pressed out to supply the place of the fresh water; and so an under current is formed, passing outwards. The circle of operations extends; and, finally, surface currents of weak brine flow in from the poles and regions of heavy rainfall to the centres of evaporation; whilst deeper, compensating currents of dense brine, take a reverse course. In this way are formed the Gulf Stream, the Japanese Kuro-Siwo, which is twice the size of the Gulf Stream, and many other ocean currents. In addition, there are local centres of evaporation, and consequent motion, in the Red Sea, Mediterranean, and similar land-locked seas. Surface currents of fresh brine run into them; and deep currents of dense brine flow out of them. Dr. Marcet found a specimen of sea water taken within the Gibraltar bar of the Mediterranean, from a depth of 4,020 feet, four times as salt as ordinary sea water. In 1849, Dr. Giraud found the specific gravity of the Gulf of Suez to

be 1,027, and the saline contents 41 per 1,000, whilst at the Straits of Babelmandeb, where the fresh current enters, he found the sp. gr. was 1,023, and the salts 39·2 per mille.

Sir W. Thomson draws attention to the effect of the trade winds in driving the equatorial surface waters from east to west, where, meeting with the Eastern shores of the continents, they are deflected, causing local currents. He attributes considerable motive power over the sea to periodic winds. Besides these steady winds, frequent gales agitate the sea, and drive large masses of water against opposing coasts, from whence they are turned off in currents. It is to the action of winds, tides, and the rotation of the earth, that we owe such differences of level as exist in the sea. Tides, by their ceaseless movements, exercise a sensible influence upon the uniform composition of the sea. Apart from the currents above mentioned, there is below 2,000 fathoms, a cold current of dense brine, chilled down at the poles, slowly moving outward from the frozen regions. On the whole, this motion is northward, since the south pole is colder than the north, and supplies the largest body of cold water.

These various currents distribute the salts in the sea, and keep its composition uniform. Another remarkable fact remains to be noticed. Though rivers are constantly discharging large quantities of fresh salts into the sea, its density is unaffected, although there is no apparent outlet for these salts. There is, however, ample provision for their removal. The purifying agencies referred to in the beginning of this chapter are still actively at work in the modern sea, building up new continents on its floor. And now that the sea teems with animal and plant life, its luxuriant fanna and flora are also ceaselessly occupied in the removal of all fresh material. In the globigerina ooze, in the growth of coral reefs, and in other directions, we see

this action in progress. The chalk cliffs of England and the Madreporic Islands of the Pacific, are monuments of such labours in the past.

The surface temperature of the ocean varies with different latitudes, and for the same latitude with different seasons. It is affected by the temperature of the atmosphere, and reflects its well marked changes. Coming home from Madras, in Feb. 1880, the author found the surface temperature of the Indian Ocean 81° F.; Gulf of Aden, 77° F.; Red Sea, 75° F.; Gulf of Suez, 69° F.; Mediterranean, 60° F.; English Channel, 45° F. The surface temperature of the Indian Ocean, in the summer months, is as high as 86° F., or 87° F., and that of its estuaries, some degrees higher. The temperature of the sea is also considerably affected by currents formed by evaporation, such as the Gulf Stream, which traverse it in various directions, carrying heat.

The warm strata heated, as before described, about the equator, extend from the surface to a depth of from three to four hundred fathoms. Those in the Mediterranean, similarly heated in the summer, extend to one hundred fathoms. All over the ocean, the temperature at a depth of five hundred fathoms, is, as a rule, 40° F. Between these limits, strata of various temperatures may co-exist. Warm strata sometimes underlie cold strata. This has been repeatedly verified in the northern seas. Capt. Belknap, U. S. Navy, "Tuscarora," mentions—American Journal of Science and Art, No. 85, 1878—that he once got a temperature of 33·7° F. at 20 fathoms, and of 38·7° F. at 200 fathoms. Temperatures of 54° F. to 56° F. are got at the bottom of the Mediterranean. Observations made during the late Challenger expedition, seem to show, that the point of maximum density is at a depth of about 2,500 fathoms. The temperature of the maximum density of sea water is 27·2° F.

At whatever depth it is found, all the water below it must be of the same temperature, for if it were hotter, it would rise, owing to its warmth, by expansion, and if it were colder, it would float up as ice.

The pressure exerted by the mass of the sea varies with its depth. It amounts roughly to one ton on the square inch for every thousand fathoms of depth. At the greatest depth measured, the pressure would be about $4\frac{1}{2}$ tons. Deep sea animals, being permeable, do not feel this pressure, but when dredged to the surface, they are found dead, as they are unable to adapt themselves rapidly to altered conditions.

It is conjectured that the sea is quite dark at a depth of five hundred fathoms. Nevertheless many creatures with good eyes have been dredged from much lower depths; and many of them brightly coloured. On the other hand blind creatures are common in shallower waters. A blind isopod is found in Lake Geneva at a depth of 55 fathoms; and Professor Jorel found that photographic paper was unacted upon by light, in Lake Geneva, after prolonged exposure at a depth of 30 fathoms. It is considered possible, however, that the mica, with which the lake abounds, is the cause of this.

The earliest geological records of life on the globe, are furnished by sea plants and animals. So vast an area, as the sea, so full of life, must occupy a very important place in the economy of living nature. Sir W. Thompson considers the most prominent biological result of the four years' work of the *Challenger*, is the establishment of the fact "that the distribution of living beings has no depth limit, but that animals of all the marine invertebrate classes, and probably fishes also, exist over the whole of the floor of the ocean." As regards life the sea is roughly divisible into

four strata. An upper one, 200 fathoms in depth, inhabited by what may be called shore forms. A second stratum, extending from the 200 fathoms line to 1,200 fathoms, peopled by a characteristic deep sea fauna. And a third, or abyssal stratum, below 2,000 fathoms, in which there is but little life, but which has not been thoroughly explored. Lastly, there is the sea bottom which is inhabited by many living plants. Plants are not found below three thousand fathoms, but oxygen exists, and food supplies might come from above. The different zones of depths of the sea are marked by characteristic belts of fauna and flora, just as terrestrial zones of altitude exhibit their peculiar animals and plants. But in the sea these enjoy, however, much wider geographical limits. There is a vast region—that which lies below the 900 fathoms line—which is cold, dark, and subject to great pressure, and is so much alike in these respects, that it is traversed by the same forms of animal life, from one end of the world to the other. There is no physical bar to this migration, since the highest submarine ridges of the Atlantic and Pacific have over one thousand fathoms of water on them.

The various and beautiful blue tints of the ocean, as pleasing to the eye as the azure arch above, are the direct result of its salinity. The darkest blues are found in the Gulf Stream, in the Indian Ocean, and the South Atlantic, where the brine is strongest. The Red Sea gets its name from floating red confervæ (Trichodesmium erythœum). It is also supposed to be the great spawning water of fishes, whose ova, red in colour, require much heat for their development; about the middle it is of a glorious ultramarine. The Mediterranean, is of a lighter saphire blue. Coast waters, affected by drainage, are often greenish,

matters brought down by rivers. The unfathomable north sea is greenish. The arctic sea, owing to melting ice, is of a pale green. And the south polar sea, where dilution is greatest, is of a still lighter green. The shade of colour is affected by the state of the sky, being lighter with a clear sky, and darker when the sky is clouded. It is also affected by the colour of the bottom in shallow water, but it is not otherwise affected by depth. The shallow, but strong waters around the Caribbean Islands; Carlisle Bay, Barbadœs; and Kingstown Harbour, St. Vincent, are blue. Whereas the unfathomable, but weak, polar seas, are green. The sea at Aden, where the fresh current which supplies the place of the water evaporated in the Red sea, is found, is pale green in colour.

To the salts in the sea we owe not only its charm of colour but also many other debts. In fact these salts, especially sodium chloride, fulfil so many necessary conditions in the economy of our planet, that we are led to see a purpose in their lavish presence in the sea. There is no particular reason why sodium chloride, which forms 76 per cent. of the total salts in the sea, should have been so abundantly present at its first formation. Judging by what we know of inland lakes, not *affected by rock salt formations*, comparatively little common salt would get into the sea through the operation of existing natural causes. And yet if it were not for this excess of salt, we should fare badly. Not to speak of the increased specific gravity of the sea, and its influence in lessening the power of storms, tides, and trade winds, which would otherwise ruin our coasts, and render navigation difficult and perilous to a degree; nor to dwell upon the obvious correlation that exists between the salts of the sea, and the great pelagic fauna and flora, dependent on these salts for existence; nor to refer to the economic,

hygienic, and other uses of these salts; nor to the glorious colour of the sea; there are two striking benefits that the salts of the sea confer upon us. By their solution in the sea, a mass of salts are disposed of, without increase of bulk, which would, if formed into dry land, considerably alter the configuration of the earth, and even the length of our day. If there be 3,138,000 cubic miles of ocean, weighing 1024·5 ounces to the cubic foot, at three and a half per cent. by weight of salts, we get 76,461 cubic miles of salt hidden away, as it were; and this not to speak of matters in suspension. Recent investigations point to a much larger quantity of salt in the sea—half a million cubic miles. Moreover, were it not for these salts, and the currents which they give rise to, which in return carry them about, equalising and distributing them, coral islands would be impossible and the physical geography of the world would not be what it is. As regards the last point, it is not enough that there should be lime in the sea, for it is so largely extracted by coral polypi from certain definite areas, that were it not for currents bringing fresh supplies, the coral polypi would yet perish for the want of it. Lastly, there is the all-important influence of the salt sea on climate.

There are four ways in which the salts of the sea control our climate. We have seen that deep saline currents are in constant formation about the equator, and at other local centres of evaporation. These deep currents are warm; their density arising from heat evaporation, they carry heat with them, as water is a bad conductor of heat. Belts of warm water, from two to four hundred fathoms in depth, are thus set in motion towards the cold regions, to supply the place of surface currents; and these warm waters, like the Gulf Stream, render cold latitudes inhabitable by

forms of life which could not otherwise exist there. They keep down glaciation at the poles. Again it is owing to its salinity that the sea contracts, and sinks out of the way of cold, below 39° F., and also resists the freezing action of cold above 27° F. Were it not for its salt, it would expand and form ice fields at 32° F. as fresh water does. Polar ice would increase in quantity, and extend in boundary, from year to year: for without warm currents, the summer heat would be unable to control it. England, for example, would be a permanent glacier region. Thirdly, the recent experiments of Mr. John Aitkin and M. Coolier have shown that watery vapour, in a perfectly pure atmosphere, free from dust, does not condense and form clouds. It remains supersaturated, but clear. For the formation of mists, fogs, and clouds, it is necessary that the air should be filled with minute particles or solid nucleii upon which the watery vapour may condense. Common salt, in a fine state of division, is one of the most effective of such condensers. When burned in a fire, or in a alcohol flame, common salt gives an intensely fog producing atmosphere. Mr. Aitkin points out the important share which the spray from the ocean, when dried, and converted into a fine dust, has in producing fogs and clouds. It is probably that we owe cloud formation at sea, which is one of the most important factors in our climatology, entirely to this cause.

Without clouds, radiation would be as great on earth as it is on the snow capped peaks of the highest mountains; and the cold at night would be of a corresponding degree of intensity. The spread of ocean ice would proceed unchecked, and glaciation would be accelerated and widespread.

Lastly, evaporation, as will be hereafter noticed more fully, is very much controlled by the salinity of the sea. It is reduced one-half in power. Thus for example, about two

inches of fresh water are evaporated in twenty-four hours, in the hot weather, in India, whereas not more than one inch of sea water is evaporated in the same time. If the sea were fresh, we should be, owing to its increased evaporation, enveloped in an atmosphere of watery vapour without clouds.

This watery vapour, under the climatic conditions indicated, would be nightly condensed and precipitated in the shape of snow or ice. Ice and snow would accumulate in such a way, owing to the combined operation of these four causes, that it is probable they would leave but a small portion of the globe habitable by the races which now exist.

Darwin, in the course of his investigations on the migration of plants, has brought to light another advantage conferred upon the natural order of beings by the saltness of the sea. He found that ripe hazelnuts, when dried, floated for 90 days on the sea, and afterwards when planted, germinated; a dried asparagus plant floated for 85 days, and then germinated. These plants, in the green state, floated for about three weeks, but not much longer. Altogether out of 94 dried plants, 18 floated for above 28 days, and some for a much longer period. M. Martins repeated these experiments under different conditions. He placed 98 seeds and fruits, of sorts, different from Darwin's, in a box in the actual sea, so that as the box rolled, they were exposed to sea and air, alternately—which would favour decomposition; yet at the end of 42 days, 18 different kinds were still floating and capable of germination. We owe it to the antiseptic qualities of the salt sea that about 20 per cent. of the seeds, spores, and fruit, which fall into it, are preserved from decomposition during their travels, and landed on distant shores in a fit state to propagate their species.

CHAPTER V.

ROCK SALT.

This chapter will be devoted chiefly to the question of the *origin* of rock salt. Incidentally it will furnish all the information available on the subject of rock salt in its other aspects.

Geologists are wont to consider the strata which form the earths' crust, as the tablets of time, written at successive epochs, on different materials, and stamped with different characters—the characters that happened to exist at the period when the tablets were formed. If we unfold the strata and examine the tablets, we find that they are superimposed, one on top of the other, not very regularly now, since earthquakes have upheaved them and denudation has blotted them out in parts, but sufficiently so to render it a moral certainty that they had been formed, one after the other, at long intervals, the lowest first, the highest last, and the others at intervening periods of time, according to their position. If we examine the characters stamped upon them, the certainty of their having been formed at successive epochs, becomes absolute, for we find the lowest stamped with the fossil remains of the beginnings of life, and those only; the others with higher and yet higher organisms added as we ascend; until we reach the highest or most recent, in which, and in which only, together with many of the preceding, the remains of man are found. Geologists assign

to the earliest of these records a date that takes us back in imagination many hundred thousand years, and students of geology, as a rule, willingly admit the accuracy of the assumption; in fact, the more willingly, the more they know about it. Here let me interpolate, for the benefit of those who dislike, on religious grounds, such wholesale inroads on time, that Hugh Miller has forged from the consideration of these facts, one of the most powerful arguments in favor of the truth of the Mosaic record—see his "Testimony of the Rocks."

These geological tablets are composed of various materials, from the flags and slates of Silurian times, to the sand and mud of yesterday's inundation. Many of these materials are repeated over and over again, showing that the same natural forces have been at work with the same substances throughout the whole record. Rock salt is one of the rocks most often repeated. It can hardly be considered a tablet itself, but it is interleaved in the record, and its position in point of time is clearly discernible. At Petit Anse, in Louisiana, a thick bed of pure salt was penetrated to a depth of 38 feet, in Pliocene strata according to Dana, or in Post Tertiary beds, according to others, as mentioned in the inaugural address of A. C. Ramsay, L. L. D., F. R. S., President, British Association, Meeting, 1880. In Pliocene or later Tertiary formations, strata of salt occur in Roumania and Galicia. The Wieliczka Mine of rock salt in Poland, the largest known, is, as far as one can judge—for its limits have not been reached yet—included in Tertiary rocks, and therefore of comparatively recent origin. Proceeding downwards in the earth's crust, or further back in point of time, we come to the rock salt which lies in Sicily at the top of the Salina clays, in Lower Miocene beds. The Trans-Indus or Kohat salt formation, which is the oldest rock in that dis-

trict, is considered by the Geological Survey to belong to the Eocene period. The salt rocks of the Pyrenees and those at Cardona in Spain, are also Eocene. In the Cretaceous rocks, salt occurs, according to Lartet, at Jebel Usdom, by the Dead Sea; and other authorities, state that it occurs in the Pyrenees, and at Biskra in Africa, where mountains of salt are mentioned as of Cretaceous age. In the Austrian Alps the salt is in the older Oolitic record. At Berg in Switzerland it is older again, in the Lias. In Central Spain at Tarragona, Taen, and at Santander in the north, rock salt is found in Triassic strata. It is found in the Upper Trias at Salzkammergut, Aussee, Hallstatt, Ischl, Hallein in Salzburg, Halle in the Tyrol, and Berchesgaden in Bavaria.

Still in Triassic records, salt is found at a depth of 3,000 feet at Sperenburg and Leith on the lower Elbe; at Stassfurth in Prussia; at Hönigsen, Hanover, in middle Keuper beds. In Wurtemberg it is in the Muschelkalk, also at Amersleben, near Calbe, and at Erfurt and Slottenheim in Thuringia. In England the Salt Mines are in the New Red Sandstone, but many salt springs issue from the Carboniferous rocks which are older still. Salt is found in the Bunter sandstones at Schöningen in Brunswick, and also near Hanover. At Salt-home near Middlesborough in the north of England, a bore hole, sunk years ago in the hope of reaching the Durham coal fields, disclosed salt at a depth of 1,355 feet, covered by Permian strata. In China, Burmah, and at Bakur on the Caspian, salt springs are associated with springs of mineral oil and naphtha, supposed to originate also in the coal measures. In the United States salt is found in the lower coal measures in Western Pensylvania, Ohio, Illinois and Kentucky. In some of these places brine springs occur also in Devonian rocks. Sir R. Mur-

chisen describes brine springs as occurring at Lake Ilmen in the lower Devonian series of Russia. The Onondaga salt group of North America forms part of the Upper Silurian rocks. The salt-rocks of the Alleghany Mountains, Washington Co., Virginia, U.S., are Silurian. A salt spring at Keswick rises from the lowest division of the salt rocks of Cumberland, in the Lower Silurian. And the Cis-Indus, or Indian salt range proper, to which the "Mayo" Mines belong, is the oldest of all, being covered over by Silurian strata. It would be, in the present state of our knowledge, useless to speculate as to the age of the "Mayo" Salt Mines. Many thousands of years separate our time from that of the formation of the Wieliczka Salt Mine, one of the most recent of the series enumerated. Intervals of thousands of years separate the members of the series, one from another; so that the "Mayo" Salt Mine must be hundreds of thousands of years old. It is at the very furthest extremity of the geological record, and its formation may be said to be coincident with the beginnings of life on our planet. So much for the age of rock salt deposits that are known, and whose ages have been determined. Other, undiscovered rock salt formations, doubtless exist.

It may be fairly inferred, as a conclusion from the foregoing, that rock salt has been forming, in an intermittent way, throughout all knowledgable time, from the Pre-Silurian period to the Tertiary; but that the Silurian and Carboniferous periods were the most prolific in such deposits. There is little evidence, that I am aware of, of the formation of rock salt in Post-Tertiary times,—a long interval, which includes the Pre-Glacial, and perhaps the Pliocenic, the Glacial, Post-Glacial, Pre-Historic, and Historic—the last, or Historic division of which, is known to occupy about 6,000 years.

We may exclude from this consideration the salt of the Runn of Kutch, and other similar superficial deposits of clearly marine origin, which do not possess the characters of rock salt; as also the formation of rock salt from solutions of rock salt previously deposited, as in the Caspian basin, the Dead Sea, the Utah lake, the African lakes, and elsewhere. Since these, though they illustrate some modes of formation of rock salt, do not throw any light on the question of its origin.

Let us now see the geographical distribution and extent of rock salt formations. As might be expected, rock salt has very wide geographical limits. It is found in all the older continents of the world, and its discovery in the newer, as Australia and New Zealand, is probably a question of time. It will be sufficient here to mention the principal countries in which it is found.

In Europe it is found in enormous quantities near the centre—that part to which it would naturally gravitate if the relations of dry land and wet were changed, and the centre of Europe were the middle of an ocean, as it doubtless was in former times.

A vast chain of salt mines extends along each side of the Carpathian mountain range, comprehending the salt mines of Wallachia, Transylvania, Galicia, Upper Hungary, Upper Austria, Styria, Salzberg and Tyrol. Recent borings made in different parts of North Germany show that a mighty salt deposit stretches from Lüneburger Heide to the coast of the Baltic. This deposit begins near Lüneburg, passes under the Elbe, and extends right across the Grand Duchy of Mecklenburg. Another branch goes in the direction of the Duchy of Holstein, *viâ* Legeberg to Elmshorn and Heide. The thickness of this salt deposit, where bored near Hagenow, is 130 metres: bottom not found. At Segeburg

about 35 miles from Kiel, nearly saturated salt brine is obtained by boring. Salt springs are found in Bavaria, Wurtemburg, and Baden. In England a large bed of rock salt lies beneath the valley of Cheshire from Malpas to Congleton. There are brine springs in Stafford, Durham, and other parts of the country. There is a salt deposit near Carickfergus in the north of Ireland, in which there are several mines at work. In France there are salt mines in the Jura (Montmoret and Grozon) Meurth et Mosselle, (Eurville and Jard) Lorr ain (Vic); Arbonne, Savoy; besides several brine springs. Spain has a salt mountain at Cardona; salt formations in the Pyrenees, and brine springs. Italy has its salt formation, as denoted by brine springs, at Montecattine, Jochia, Battaglia, etc. In Switzerland salt is found at St. Maurice; brine springs at Bader, Argovie Wildegg, and other places. Rock salt is found at Missolonghi in Greece. It has been recently discovered near the centre of European Russia.

Many extensive rock salt formations, occupying from 1,500 to 2,000 square miles of area, lie in the north of India, and stretch away towards Afghanistan in broken hill ranges of salt. These are called the Cys-Indus and Trans-Indus salt regions. They are in a manner linked on to the Afghanistan salt deposits, which are also extensive: and these again with those of Persia and Tartary, which conduct us to the Asiatic steppes of Russia, the provinces of Astrakhan and Orenberg, and so back to Europe. Further East, rock salt is found in Siberia, Burmah, Tibet and China.

In North and South America salt is found in Virginia, (Washington Co.,) Nevada, the Andes, the Alleghannies, the Salmon Mountains of Oregon, the Island of Petit Ause, Lousiana; Bolivia, and Peru. At St. Domingo and other West India Isles, and in an island in the Gulf of Mexico.

In Africa it is found in the northern Highlands, Algeria, Tunis, and Morocco. The great salt rocks of the Tegaza are situated to the west of the desert of Sahara, a little distance from Cape Blanc. This salt is that which is brought by Caravans to Timbuctoo. Salt is also found at Taudeni in the Sahara, and in Madagascar.

As regards its present level in the earths' crust, rock salt is found at the surface, and at various elevations, above and below it. It is also found above and below the level of the sea. At Speremberg salt is found 4,000 feet below the surface. The Wieliczka Mines are 1,000 feet below the level of the soil, and 400 or more below that of the sea; their lowest limits are undiscovered. At Middlesborough-on-Tees, rock salt was found in a bore hole at a depth of 1,293 feet. At Cardona, in Spain, a mountain of rock salt, the depth of whose base is unknown, rises to upwards of 500 feet. The Trans-Indus salt hills reach an elevation of 200 feet. The great salt lake area of lake Utah, equal to about 2,000 square miles, is situated at an elevation of about 4,000 feet, in the Rocky Mountain district. The rock salt at Hallien, near Salsbourg, is 3,300 feet above the sea level; and that at Arbonne, in Savoy, is 4,000 feet higher, being perched in the region of perpetual snow at an elevation of 7,200 feet above the sea level.

The physical characteristics of rock salt, and the formation of its beds, will claim our attention before we can satisfactorily attack the problem of its origin; but as these considerations lead up directly to the question of origin, it is as well to open that question here.

A good deal of obscurity shrouds the origin of rock salt deposits, and geologists are not all agreed as to their mode of formation. Dr. Fleming, who surveyed the geology of the Indian salt range in 1848-53, attributed the salt for-

mation to eruptive agencies, as the result of his own observations. Sir R. Murchison says that other distinguished geologists have arrived independently at the same conclusion. Dr. Macculloch remarks of all rock salt formations, "The purity and solidity of the masses of rock salt, their bulk, their insulated and peculiar positions, with many other facts on which I need not now enter, prove that they could not have been derived from the ocean in the manner thus supposed (by solar evaporation) nor probably in any manner. They are special and original deposits, in whatever way produced." On the other hand the majority, perhaps, of writers upon this subject, look upon rock salt as being a sedimentary rock, of aqueous origin, and formed from the sea. It is nevertheless admitted that the aqueous theory is open to several and serious objections, which require to be overcome before the theory can be finally established.

Rock salt is as unlike sea salt, as we know it under the form of "bay" salt, as any two salts having the same composition could well be. Rock salt, in some places, as in the Trans-Indus range, and at Cardona in Spain, for example, forms solid masses rising out of the earth for hundreds of feet in cliffs and mountains; in others, it lies deep in the bosom of the ground—a hard rock—which has to be mined with pick and blasting-powder.

It is for the most part translucent, and of a bluish or pinkish color, resembling masses of dimly transparent, flawed glass; yet, fine blocks of colorless, transparent salt occur in nearly all mines. A rectangular, polished block of pure salt, 37½ cubic feet, weighing 2⅕ tons, was sent from the "Mayo" Mines to the Vienna Exhibition. Newspaper print can be read through more than six inches of such transparent rock salt. It is as hard as, or harder than, gypsum, and various fancy articles, such as balls, platters, salt-

cellars, etc., are turned from it on the lathe. In continental mines it is worked up into statuary having the light effects of alabaster. It forms the pillars, stairs, and horse stalls, used in the rock salt mines.

If we examine closely, however, we find that in all its other properties—chemical, physical, therapeutic, organoleptic, etc.—there is no difference between rock salt and ordinary bay salt. Rock salt, like sea salt, crystallizes, in the first, or cubic system, as is demonstrated by its cleavage, and by isolated crystals found scattered through the mass. Rock salt is stratified. It occurs in beds, varying from a few inches to 1,200 feet, and more, in thickness. In the "Mayo" Salt Mine, the whole formation is calculated to be 600 feet thick, composed of strata, each of which is supposed to represent one year's deposit. These strata vary in thickness from 6 inches to 20 feet, and are separated from each other by clay beds, red gypserous, and violet marls. It is found that the salt is purest, and least stained, in the middle of the seam. In Cheshire, the rock salt is found in horizontal strata, separated by beds of clay and gypsum. Salt crystals are found infiltrated through some of the clay beds. In Wurtemberg, the salt is enclosed in seams of shell limestone. At Ischl, in Upper Austria, it occurs in horizontal bands, running through the mountains overlooking the town. These mountains are composed of bands of limestone and rather impure rock salt, separated from each other by colored gypserous marls. The limestone above the salt is scarcely distinguishable in structure or fossils (Oolitic) from that below it. Without giving further illustrations, it may be said that it is an admitted fact that rock salt is a stratified formation.

In general outline, beds of rock salt are seldom of uniform thickness; they are thickest about the centre of the deposit,

and thin out towards the circumference, having a lenticular formation. They are often linked together, forming chains, and when so connected, lie in about the same horizontal plane. The importance of this we shall see presently.

The salts associated with rock salt are precisely those which are formed in association with it in the manufacture of common salt from the sea, as gypsum, sodium and magnesium sulphate, potassium and magnesium chloride, &c.

We have now before us, as many of the ascertained properties and relations of rock salt, as will be useful in guiding us to form an opinion of its origin. It will not have escaped notice that most of these mark it as a sedimentary rock of aqueous origin. I will now proceed to examine, in detail, its claims to be considered as an aqueous rock.

Many salt areas, or salt regions as they are called, are made up of a number of salt deposits, linked together, as it were on one horizon. The explanation of this phenomenon is so intimately associated with the theory of the gradual upheaval of areas of dry land from the ocean's bed, that we must examine both theories together here. One can easily imagine that if large tracts of undulating country, forming natural basins, were submerged in the sea and brought to the surface again, the natural basins would be filled with salt water, which would, on evaporation, yield linked salt deposits of the kind referred to. Now this is almost precisely what is believed to have happened, for it matters little whether the undulating surface, was an original sea-bed, or one formed by subsidence and re-elevated.

The theory of the gradual interchange of dry land and ocean, which is as well established as any demonstrated geological fact can be, is associated in many ways with the study of the origin of salt deposits. It is of the greatest importance in explaining the wide geographical distribution

of rock salt. It is the key to its position in so many pages of the palæontological record, from the Tertiary to the Silurian era. It furnishes the reason for the otherwise inexplicable position of rock salt deposits at various elevations above, as well as below, the present sea level.

It is believed by geologists, that slow upheavals and subsidings of land have been going on since the beginning of things, as far as we can trace them; that most of the dry land has been washed, by gradual denudation, into the sea, and deposited within 200 miles or so of its margins; that other dry land has risen from the skirts of sea to take its place; and that there have been compensatory sinkings as well as upheavals. This interchange of places between the bed of the ocean and the surface of the ground has not taken place once, but often; so that scarce any land exists, except the tops of high mountains, which has not had its turn, more than once, above and below the water. The skeleton of the earth, its great mountain chains and ocean grooves, remain in the lines laid down by the marine contortions of its early secular cooling, but all else is changed.

If there were such upheavals of large and comparatively shallow areas from the salt sea, we should find salt deposits upon them. That there were such partial elevations in Pre-Silurian times is evidenced, *inter alia*, by the rock salt formations of the Indian range. The salt rocks of England go to prove the same thing for the Carboniferous era; those of Switzerland for the Lias; those of the Austrian Alps for the Oolitic; and so of the rest, up to the Tertiary period, in which we find the Wieliczka salt mine. The covering strata lying over these rock salt deposits moreover demonstrate, that the deposits have, after their formation, sunk again into the depths of the sea, and, whilst some have remained there for ages, before coming to the surface, others have

oscillated, as it were, above and below sea level. Hence we find layers of rock salt, separated by intervening sedimentary strata, placed over each other in irregular succession, and covered in by other sedimentary rocks. This last fact, however, I will account for presently in another way.

We have other evidenee that these. elevations of fixed areas were partial; that they took place in each succeeding epoch; and that they were widely distributed over the face of the globe. Rock salt formations confirm this evidence in a conclusive manner, and they further tell us what areas were elevated, and at what periods. Note also that rock salt deposit are almost invariably found in mountain valleys as in the Jura, in France and the Malvern valleys in Cheshire, etc.

It will be seen, therefore, that the assumption of the marine origin of rock salt is closely linked with that of the movement of the earths' crust, which ranks as a well ascertained fact. In this connection it is curious to note that the workmen, cutting through the Suez Canal, met with a large deposit of rock salt, in the locality, now known as the "Bitter Lakes." This deposit, which then lay beneath the desert sands, now lies at the bottom of an extensive salt lake. If any accident should permanently close the Suez Canal, this salt bed and the sandy stratum overlying it, would be covered in by another rock salt deposit, formed by the evaporation of the lakes.

But there is also much internal evidence in rock salt formations that they were formed from the sea by deposition. Rock salt deposits are described as lenticular, that is to say, the *greatest depth* of the salt is found *in the centre* and as the edge is approached the deposit thins out and diminishes. The same description applies to most natural basins, whether lakes or seas. If rock salt were of aqueous

origin and formed from marine basins, the deposit would have the shape of the basin, below, whilst plain above; it would form a plano-convex lens, thick in the centre, and thinning out to the circumference; convex below, and plane at the surface, such in fact as we find it. Here is another strong presumption in favor of its marine origin.

But rock salt is also a stratified rock. When undisturbed, it is found in horizontal beds, and these beds are often interleaved and separated by others of clearly aqueous origin, as gypsum beds, sandstone, limestone, marl, &c. Stratification is admitted to be one of the most distinctive marks of the aqueous origin of a rock formation, and this stratification, in alternate layers with sedimentary rocks, is almost conclusive proof that rock salt itself is sedimentary.

Although, for reasons that will be given presently, rock salt deposits are by no means fossiliferous, still bivalve and other marine shells, casts of fish, &c., are not wanting in most deposits to testify to their marine origin. In the *Cis-Indus* salt range, the oldest known, shells of one genera of mollusca have been found. A block of rock salt from the Wieliczka Mine—the youngest mine of rock salt and about the finest in the world—examined by Professor Philippi, was found to contain 5 zoophytes, 1 echinus, 1 serpula, 7 conchifers, 8 univalves, 3 crustaceans, and a cirithium identical with one now living in the Mediterranean. Fossil bones occur in the gypsum of the Paris basin, and in the salt of the Runn of Kutch. Such instances might be multiplied.

Again, certain other salts of peculiar significance, as calcium sulphate, are almost invariably found associated with common salt in rock salt deposits. At Stassfurth, in Prussia, magnesium sulphate is found; and lately, a large deposit of sodium sulphate was discovered there. At Vilia Rubia, in Spain, glauberite, a compound of the anhydrous

sulphates of lime and soda, occurs in the salt. In the "Mayo" Mines, magnesium sulphate and chloride are found in combination with other marine salts. T. Sterry Hunt states, on the authority of Nicol, that in some specimens of Cheshire rock salt, small cavities have been found, containing a strong solution of magnesium chloride and some calcium sulphate. One or more of these salts have been found in connection with all salt mines, which have been thoroughly explored. Now, these are, as before stated, precisely the salts which are formed naturally, wherever sea-water is evaporated to dryness. They do not all form at the same time, or temperature. Magnesium sulphate for example, in sea brine, changes, at the freezing point, into sodium sulphate. Magnesium chloride is so very deliquescent that it rarely can be obtained by solar evaporation. Moreover there are excellent reasons connected with their solubility, to be hereafter noticed, to explain their absence. We could not therefore expect to find them all present in a single salt mine. It is enough, therefore, that we do find them all represented in different rock salt formations.

As illustrating in a practical way the relation of modern sea salt formation to ancient salt deposits, it may be interesting to mention that a few years ago, a French company, which had a very large business in the manufacture of sodium sulphate by the winter evaporation of sea brine, was obliged to stop work, owing to the discovery of a large deposit of this sulphate in the Stassfurth rock salt mine.

But the most emphatic instance of the association of sea salts with rock salt is to be found in the presence of gypsum. Gypsum, or calcium sulphate, is a very insoluble salt, and therefore one of the earliest deposited in the evaporation of sea brine. It deposits from sea water when the latter is evaporated to about one-half of its bulk, almost irrespective

of temperature. As, owing to its insolubility, it is rarely taken up again, we would expect to find it with rock salt, if the latter were of marine origin. As it happens, we do find it. Gypsum is always present with rock salt. They go together so much as a matter of course, that even the unobservant Afghans have taken notice of the circumstance, and have christened gypsum, "the brother of rock salt." But the relation of gypsum to rock salt is peculiar and will have to be gone into more particularly, when reviewing the objections to the theory of the aqueous origin of rock salt.

Rock salt, and the gypsum associated with it, are often stained by colored clays, a variety of hues, of which, however, pink or some shade of red, is the most common. Common salt, manufactured from the sea, with indifferent care as to cleanliness, is much stained with the same colors. It is remarkable that a pink scum forms on the surface of the brine at many salt manufactories, staining the salt a pink color; so that the produce of some salt works may be known by this tinge, even as the produce of some salt mines is known by its red shade. It would be useless here to enter into a discussion as to the nature of this coloring matter; it is either organic, or an oxide of iron. It may be one or the other, according to circumstances. Professor Ramsay says, that he has, for many years, considered this red color to be apt to indicate deposition of sediments in *inland lakes.* He also remarks of the Permean salt groups, that the gypsum, the dolomite, the red marls covered with rain pittings, the sun cracks, and the impressions of footprints of reptiles made in the soft sandy marls, all point to the fact that our Permean strata were deposited in a salt lake, or lakes, once connected with the sea.

We now come to the crystalline structure of rock salt, and here we touch the edge of the difficulty regarding the

aqueous theory of its formation. It is objected to this theory that the homogeneous, transparent, crystal structure of the rock, is quite unlike any product of the evaporation of salt water as we know it. Such indeed is the case. There are, however, some inland salt lakes from which we may take a lesson with advantage. Lake Oroomiah, in Persia, and the Elton Lake, in the lowest part of the great Aralo-Caspian plain, offer examples of the formation of rock salt by deposition in the beds of inland lakes which are gradually evaporating and filling up. Lake Kosiak, situated on the right bank of the Irtysh, in Asiatic Russia, is a similar example. Some of the zoutpans, in South Africa, are likewise solidifying. But the best illustration is found in Lake Inder, which lies in the valley of the Ural River. The bottom of this lake is an immense solid mass of salt, covered with a shallow sheet of brine. At the end of summer, the lake entirely dries up, and forms one solid block of salt. These lakes teach us that large masses of solid salt may be formed in comparatively small areas, by evaporation, under certain climatic conditions, even at the present day, and that salt, so formed, is massive, and resembles rock salt.

Let us consider the conditions which prevailed when the old rock salt was formed, as far as they affect crystalline structure. Some deposits, it will be remembered, are 1,200 feet in thickness. Considering that it takes about 6 cubic feet of saturated brine to produce one cubic foot of salt, and that, when salt deposits, the brine has a specific gravity of 1,208, and lies in the deepest hollow of its basin, we can imagine what an enormous depth of dense brine must have presided over such salt formations. The salt must have been formed at profound, motionless depths, in which the stillness was only broken by the growth of crystal structure.

It must have been formed under gigantic pressure, from such depth and density of brine. We have no parallel to these conditions of crystal growth, at the present day; we can only imagine, *à priori*, that the resulting crystal must be very perfect, resembling glass.

But the effect of crystalline contraction, the effect of lapse of time, and the effect of superincumbent pressure have also to be considered. The force of crystal growth is a very powerful one. Where, as in the growth of ice, it takes the form of expansion, it bursts iron pipes with ease. In salt masses its tendency is to contraction, to perfection of crystalline structure; given a sufficient lapse of time, and suitable conditions, and it will effect its purpose. What period of time has this force had at its disposal in the most recent of our mines of rock salt? As before stated, many thousands, or, many tens of thousands of years. During all this time, moreover, what pressure has been at work on the salt mass, crushing it down, with the irresistible force of the most powerful hydraulic ram, into a solid homogeneous mass? The pressure, like the time, is beyond our computation; we can only measure it by its effects. We see the rock salt sometimes interleaved with sedimentary masses, which have been crushed into compact rocks. We find it covered over with hard coal, which we know to have been, once, a loose vegetable deposit. We find a variety of other rocks, overlying the salt, bearing the same testimony with more or less force; and in some cases, as in the Austrian Alps, we find the salt buried, at the present time, under masses of rock, whose weight and pressure we can calculate. What wonder, therefore, that rock salt is a crystalline mass, and not as the salt deposits recently formed in our shallow bays. If the case were otherwise, there would be good ground for rejecting the marine hypothesis. Let it be remembered that the

protozoa, whose fossil remains make up the chalk cliffs of England, were swarming in life, in our northern seas, long after the deposition of all but the most recent beds of rock salt.

Another peculiarity of rock salt, which is held by some to tell against the marine view of its origin, is the rare presence of fossil shells and fishes, &c., in its formations. It is argued that if this salt was deposited by the evaporation of an inland sea, we should find abundant organic remains in it, as we know that salt acts antiseptically, that is, it preserves organic remains. This comparative absence of fossils, can, however, be explained on natural grounds. Life ceases to be supportable in brine of a certain density. In marine salt works, it is found that the mollusca, crustacea, fishes, &c., which find their way into the salt beds, whether voluntarily, or through the agency of the lift pumps, begin to work their way out expeditiously, by all possible channels, as soon as the brine reaches a density of 5°, or 6°, Beaumé; and that at 7°, or 8°, Beaumé, those left behind, sicken and die, so that at 9° Beaumé, not a living animal is left in the brine. At 7° Beaumé the sea water has been reduced, by evaporation, to about one-half its original bulk; gypsum is depositing and continues to deposit for some considerable time, until the brine is reduced to one-quarter of its original bulk; but common salt has not formed, nor does it form until long after, when only one-tenth of the original brine remains. So that, if we imagine that all possible means of escape were cut off from the inhabitants of our evaporating sea, and all had perished, we should find their remains buried in the soft mud under the gypsum, which would subsequently cover them over with a thick deposit. But, there is reason to suppose that the gradual elevation of salt areas was a protracted work of time, in which opportunities were

afforded for the living contents of the rising estuary, or sea, to join the main ocean, before evaporation had made the brine uninhabitable. We can easily conceive how, at the first warning of increase of density, every living creature would make for the connecting straits and shallows, and dart into the great ocean; and how finally, some molluscs and crustaceans, overtaken in their slow flight, would fall, die, and be buried, at the extremity, or confines, of the shrinking sea, far away from its central salt deposit. In point of fact, almost all salt deposits do contain the fossil remains of a few specimens of the marine fauna which existed at the date of their formation, and not seldom in the rock salt itself; from which it may be argued, with a considerable approach to certainty, that these marine specimens lived and died in the neighbourhood, and were washed into the deep salt area, from the surrounding gypsum, after salt formation had commenced.

The most serious objection to which the aqueous hypothesis is open is founded upon the abnormal position of the gypsum. It overlies the rock salt, at some places, instead of being beneath it, as it should be, theoretically, since it is much the less soluble salt and the first to deposit, and since it does practically lie under the salt, in the rectangular artificial basins of *salines*. This is unquestionably, at first sight, a difficulty. It is not, however, an insuperable one. There are various ways of accounting for the anomalous position of the gypsum, and some of these ways have much force and ingenuity about them. Some argue that the gypsum was originally deposited beneath the salt, but that it was subsequently removed by subterranean denudation, by hot springs or currents, forcing their way up from lower levels. Others think that upheavals and overthrows, caused by the secular cooling of the earths' crust, or by volcanic action,

of which we have much evidence in the condition of the salt and other rocks, may have led to a reversal of the original order of the deposit. It is said, too, that we can hardly deduce from theoretical and observed conditions, at the present day, the sequence of events which took place remote ages ago, when some of the conditions of soil and brine were certainly different from what they are now.

I am of opinion that the explanation is, after all, not very far to seek. There is no difficulty, whatever, in accounting for the presence of gypsum, on the top of the salt deposit, or in strata running through it. The problem lies in the absence of gypsum beneath the salt. Now, as to this, gypsum is found at the bottom of the salt deposit at many places which have been worked out, or have been exposed in section. It is so found at Ischil, in Upper Austria, at Wimpfen, in Wurtemberg, and at other places. And it may be said, too, of the great majority of rock salt formations, that the true bottom has never been explored. In many cases the bottom of the rock salt has not been reached; in many others, as in Cheshire, where rock salt strata alternate with strata of marl, the exploration is given up as soon as inferior salt is tapped in deep workings, or, as soon as marl is found underlying it, at unprofitable depths. The lowest stratum of rock salt overlying the gypsum is generally so inferior, and mixed up with gypserous marls and shell limestone, as at Wimpfen, that where these things are done for profit, exploration is at once abandoned. It is most probable that gypsum does underlie the salt oftener than is suspected, but as will be shown directly, it is not essential to the aqueous theory that it should do so.

The way in which gypsum comes to overlie the salt deposit is this. Gypsum attains its maximum of solubility when the density of the sea brine equals 4° Beaumé, or

specific gravity 1,033°. If the volume of ordinary sea water be taken as 1,000, its volume, after it has been evaporated to the density specified, will be about 850. As there is sufficient gypsum to form a saturated solution, any further diminution in volume, accompanied as it must be by increase of density, tells on the contained gypsum, a portion of which becomes insoluble and separates. This deposition of gypsum from sea brine continues from volume 850 until the volume of the sea water is reduced to 100, or to one-tenth of its original bulk, at which point hardly a trace of gypsum remains. At this point the deposition of common salt *begins.* We have now to consider the shape of the sea basin in which the deposit is taking place. Professor H. Mosely states that as a general rule, the sides of ocean basins have a very gradual slope, and are inclined at an angle of two or three degrees, so that a locomotive engine could run up them with ease. Without going into mathematical figures, it is sufficient to observe that it has a slope from the circumference to the centre, and that as the volume of the sea diminishes from 1,000 to 100, its waters naturally gravitate towards the centre, or deepest part, into which they finally subside. It is precisely whilst this shrinking is going on, from 850 to 100 volumes, that gypsum is being deposited, so that when the brine reaches the centre, where salt is ultimately deposited, very little, or perhaps no gypsum may be left in it. It all depends on the configuration of the sea bottom. In all ordinarily shaped sea basins, therefore, having shelving shores, sloping to a central abyss, we will have a large deposit of gypsum laid bare by the receding brine, and in most cases the whole of the gypsum will be thus left behind, away from the salt.

What follows is this. Common salt is deposited alone in a large circle, in the centre, or deepest part of the sea bottom.

This may go on uninterruptedly until all the salt has been parted with, in which case, we would have a large central salt deposit, surrounded by a much larger circle of gypsum, deposited on a slope, at a higher level. It only needs the intervention of rain and flood to complete the picture; the gypsum is washed over the central salt deposit and settles upon it, covering it over with a thick impermeable stratum, which protects it from further injury and seals it up for future use. But more likely, storms will overtake the process more than once, before its completion, and floods of gypsum and mud, with mollusk shells perhaps, will contaminate the brine, and settle down upon the salt, which, in its turn, will form again upon the gypserous bottom; and so alternate layers of rock salt and gypsum, or gypserous marls with shell limestone, &c., will come to be formed, precisely as we find them.

After an uncertain lapse of time, this salt basin would be completely filled up, by the gradual deposition of sedimentary matters carried in by streams, or by the dust of aerial currents. Once filled up, a rock salt basin loses the power of drawing solid materials to itself. It remains concealed; or is unearthed by denudation; or exposed by volcanic action, or by the secular cooling and contraction of the earths' crust with upheaval in irregular mountain thrusts. The contorted strata of many rock salt deposits tell of the pressure and crushing to which the salt has been subjected by these very movements. Indeed, the present stratigraphical condition of many salt deposits, and the myriad cracks and flaws in the salt crystal, can hardly be attributed to any other cause. In whatever way produced, streams will sometimes cross the site of a salt formation, and the work of denudation will be in time accomplished. Streams will grow into rivers, which will cleave across the ancient sea

basin, cutting it down from its topmost stratum to the base of the rock salt deposit, or lower still; and as the work progresses, hills and cliffs of rock salt, with their gypsum, and other coverings, will grow up on either hand, as at the Trans-Indus salt range, and at Cardona in Spain. Or it may happen that the site is not the scene of powerful denudation, and that the rock salt will be buried out of sight, and out of knowledge, for an indefinite time. Or that the movement of elevation continues until the rock salt lies secure at such altitudes as at Hallein, or Arbonne, where it is actually found. Or that movements of depression carry the region once again to the bottom of the ocean, where the rock salt, secure beneath the gypsum, receives an enormous addition to its other coverings. All these are not only possibilities, they are certainties, and have happened.

We have now disposed of the chief objections to the marine view of the origin of rock salt. There remain some minor objections of comparatively little account. Superior salt is sometimes found crystallized in lenticular, or ring-shaped masses, in the midst of inferior salt; this is not a usual sedimentary arrangement; it is a difficulty. But, when we consider that we have to deal with crystalline masses of unexampled extent, and with crystalline forces which are imperfectly understood, this crystal, within a crystal, has nothing startling about it. It exemplifies, in crystal masses, a form of natural selection which we see illustrated by concretionary nodules, elsewhere, and by the lenticular gypsum crystals which are found in salt marshes.

Again, veins of rock salt, at various angles, are found running through the stone, or indurated clay beds, associated with rock salt in some mines. At Cheshire, for instance, such veins occur in the flag beneath the salt. They always take a vertical direction, however; and from the

nature of these stones, it is not difficult to suppose that they may have been traversed by cracks and fissures, into which brine would percolate and crystallize. The salt is crystallized, and not fused in the veins, as it would be, if of igneous origin; and very perfect cubic crystals are often found in such situations. In fact the finest salt is found near the veins.

These difficulties, which are of little account in themselves and easily explained away, lead up to the igneous theory of the origin of rock salt. The presence of sodium chloride in hot springs is taken as evidence in the same direction, as is also the presence of common salt in the eruptive matter of Mounts Vesuvius and Heckla. All we know about hot springs, is, that the water comes from a distant and warm region, and that it takes up in solution more or less of the soluble salts it comes in contact with. Rock salt deposits are abundant enough in most parts of the world to account for the presence of salt in such springs. Hot springs are very common in the salt regions of China and Burmah. Perhaps the association of coal and mineral oil with salt, may account for the heat, as well as for the saline phenomena of such springs. As to Vesuvius, the salt formed in its eruptions is associated in such proportions with the minerals which invariably accompany rock salt formations, that geologists have little doubt that the volcano is situated over an ancient salt bed. Montichelli and Covetti speak of the salt thrown up by Vesuvius in 1805. In the year 1822, so much salt was discharged from Vesuvius, that the villagers quarried it for use, until it was claimed by the crown. (Ann. de Chym. et Phys., vol. 27, p. 92.) Primary and eruptive rocks contain but little trace of sodium chloride. It never forms dykes, and there is no stratigraphical or other evidence of its igneous origin.

In fact, it may be said, that the igneous theory takes its origin, not in any positive evidence of igneous action in rock salt, but in the evidence afforded by the position of gypsum, and other facts, apparently excluding the aqueous theory. Hence the consequent necessity for starting some other theory to explain the existence of rock salt. It is true that semi-anhydrite, a sulphate of lime, crystallizing with 6·21 parts per cent. of water, which forms only under pressure and at high temperatures, is sometimes found in the Indian salt ranges. But this need only confirm the evidence, which is otherwise strong enough, that many rock salt formations have been subjected to volcanic action. There are fatal objections to the igneous theory which practically put it out of consideration. The association of rock salt with naphtha aud petroleum is justly held to exclude igneous action, since these would otherwise have been burnt off and volatilised. The unburnt organic remains, the unburnt coal, and the presence of unburnt gypsum in all salt formations, are convincing proofs that these formations had not a birth and baptism of fire.

Before leaving this part of the subject, let us give attention to the remarkable provision of nature which places gypsum, one of the least soluble of rocks, uniformly, as a covering, over sodium chloride, one of the most soluble, as, to this, in all probability, we owe the preservation of the vast stores of rock salt which now exist. If the presence of salt everywhere is considered an evidence of design in the creation of the world, how much more so is this arrangement, which so effectually preserves it through untold ages of cosmic change.

The modern study of volcanic action, far from proving the igneous origin of rock salt, has brought to light the true connection between volcanoes and the sea, which is that of a steam engine with its water supply.

The following analyses show that the salts thrown up by Vesuvius are those which occur in the sea which bathes its feet:—

ERUPTIONS OF VESUVIUS.

	A.D. 1822.	A.D. 1855.	A.D. 1856.
Sodium Chloride ...	62·9	94·30	46·16
Potassium „ ...	10·5	...	53·84
Magnesium „ ...	...	0·60	...
Calcium Sulphate...	0·5	0·70	...
Sodium „ ...	1·2	0·20	trace
Potassium „ ...	...	1·00	...
Magnesium „ ...	...	0·40	...
Silica ...	11·5	...	...
Oxide of Iron ...	4·3	...	...
Alumina ...	3·5	...	...
Lime ...	1·3	...	...
Water ...	3·7	...	...
	99·4	97·20	100·00
	Laugier	Deville.	Bischof.

Heckla is incrusted with salt and the great geysers further inland contain 14 grains to the gallon.

It has long been suspected that a very close relation exists between volcanoes and the sea. The maritime position of the greater number of them, and the presence of marine salts in their fumeroles was evidently more than a mere chance connection. The juxta-position of sea and fire, furnish the materials for producing steam, and steam is capable of doing the work known as volcanic action.

The existence of subterranean fires is a sort of geological axiom, and where there are fires, there are cracks, and occasional ejections of molten material. On the dry land we see the evidence of such action in trap dykes, and geysers; under the sea, we may infer similar action when volcanic craters unexpectedly appear—as in the Pacific, where certain islands are craters, and nothing more. We may also infer it when the sea boils, and marine geysers appear, as sometimes happens. But under the sea the conditions are not the same as on the dry land, for water, with a pressure of several tons to the square inch, lies over the crack, and thereby gains admission to the fires below. What follows is a struggle between the opposing elements, fire and water. When fire is in the ascendancy, grand

explosions of steam, laden with lava and sea salts, fill the volcanic vents, if happily such there be to carry them off. When no vent exists or is burst open, the force expends itself on the diffluent under-crust of the earth, in a series of expansion waves, propagated to a distance, and known as earthquakes. M. Mallet supposes that the water assumes the spheroidal state, and after a time, when cooled, explodes—producing the effects described. Most observers are agreed that a close connection exists between volcanoes and earthquakes; and they are invariably noticed to be in activity together, or supplemental to each other.

Sir Charles Lyell says, "The experiments of the most eminent Chemists have gradually removed, one after another, the objections which were at first offered to the doctrine that the salt water of the sea plays a leading part in most volcanic eruptions." He thinks that the presence of the incumbent body of salt water explains the preference of volcanoes for marine situations, since the interior of continents are comparatively dry. M. M. St. Claire Deville and Fouqué have shown that the solid and liquid matters of volcanic eruptions accord perfectly with the theory that salt water is disintegrated in the foci. The fumes of hydrochloric acid accompany the lava, and deposit common salt; and the magnesium salts are decomposed, leaving the magnesia.

Salt Mining.

Quarrying.—Where rock salt occurs in natural exposures, as at Cardona in Spain, the Trans-Indus salt region, Nevada in the U. S. and other places, it is quarried in the side of the rock, or in pits, as may be most convenient. At Cardona, it has been quarried down the perpendicular faces of the salt cliffs. At Nevada, from six to twenty miles up the Virgin River, a series of openings have been made in the salt formation in the mountain side, and from these the rock salt is thrown out in great masses, by a three or four foot blast. Formerly, in the Trans-Indus salt region, the natives worked in pit quarries. After a time pit quarries become dangerous, as the overhanging rock not unfrequently falls in and buries the quarries; besides they are liable to be

flooded and thrown out of use. Dynamite is now generally used for quarrying. At Kirghis, in South Russia, rock salt is quarried in the sides of pits; the seams are cut vertically into blocks, which are then hammered at their free extremities, by means of a rude timber battering ram, hung from a triangular wooden support, which causes each block to separate from its floor, through cleavage. The caravan salt brought to Timbuctoo is quarried by the Moors from the Tegaza salt rocks to the west of the desert of Sahara.

Mining.—When salt seams are covered in by other strata, they have to be got out by shafts, vertical or horizontal, as the case may be, from whence galleries are driven through the salt seam, as in coal mining. Only the purest part of the seam is attacked; the upper and lower portions, technically the roof and floor, are generally dirty, stained, and unfit for use. Considerable difficulty often attends the sinking of the shaft, owing to the common presence of subterranean water-ways in such districts. This difficulty was much felt in former times, when square timber shafts were used, and the means of pumping out the flood were scarcely adequate. At present, cast iron cylinders, in pieces, jointed with india-rubber, are used for lining the shafts in Cheshire.

The space between the iron and the wall of the shaft is filled up with cement, to prevent incursions of water; and the cylinders are, with the same object, rapidly pushed on and finally imbedded in the salt below. Powerful steam pumps are used, when necessary, to clear the works of water. At the Wieliczka Salt Mines there are numerous shafts for pumping, workmen, horses and the exit of salt. Where the descending shaft passes through clay, or loose soil, walls of rock salt were built into the sides of the shaft to support

them, by the following ingenious plan. Blocks of salt were superimposed, like bricks, and afterwards water was poured over the wall thus formed. This water dissolved some of the salt, and as it evaporated, left it in the chinks and crevices of the wall, where it acted as a cement and bound the blocks into a solid mass. At Ischl the salt mines are tunnelled in horizontal galleries from the face of the mountain, and are entered by means of a *rutsch* at the inner end of the tunnel. The *rutsch* is a slide cut on the slippery salt at an angle of 40 degrees, sloping into the mine. The miners sit on logs of polished fir and descend the *rutsch* with breathless speed. There are steps along the wall of the slide and a projecting rope by means of which the ascent is made; but the steps are too slippery to descend with safety. Many of the Wieliczka openings are in the form of special staircases; but as a general rule steam windlasses and cradles, or tubs, are used for the passage of vertical shafts.

When good marketable salt has been entered, galleries are driven out from the shaft in all directions: for as the deposit is lenticular, or nearly circular, it can be worked all round the compass.

The galleries are formed in steps, blasted out from above downwards; and as the salt is broken out, it is sent up the shaft to store. The openings are made from 15 to 30 feet high, according to the thickness of good salt; and as the passages are formed and extended, their arched roofs are supported on either side by large square pillars of salt. In their final dimensions, the galleries vary very much in different mines, and even in the same mine. In the Marston Mine at Northwitch, which has been worked since the end of the 18th century, the distances between the pillars varies from 12 yards in the old workings, to 25 and even 40 yards in the newest. The pillars are about 10 yards square and 10

yards high. The due provision of strong pillars at regular intervals, to support the roof, is one of the most important points to attend to in mining. As galleries are frequently driven beneath galleries it is only by regularity and measurement that the position of pillars can be ascertained. In the Wieliczka Mine there are five stories tunnelling through the salt, and each story is separated from the next by an interval of about 100 feet. The lowest depths of this mine have not yet been reached. In India some of the old, but unexhausted mines, worked by the natives, have now become inaccessible, through the falling in of badly-supported roofs, and the dangerous condition of the parts still standing.

The seam is worked from above downwards,—first, by horizontal or angular bores driven into the top of the wall, which is reached by means of steps cut in the rock salt, and by the aid of a rope attached to a spike in the top of the wall. As soon as a pathway, or drift, 5 feet broad and 5 feet high, has been formed, the men work down, boring about 3 feet from the edge of the drift, and blasting out the wall. In Cheshire the wall is cut with 3 drifts, called locally, top cut, middle cut, and soil cut. The bores are made with ordinary crowbars, tipped with steel. They are made 3 feet deep and are loaded with half a pound or more of gunpowder. The fuse is made with a straw, filled with gunpowder, and packed into the bore with small bits of salt. Before firing a blast, the men in the vicinity are warned to get into a place of safety. The fireman who lights the fuse, runs to cover. About three tons of salt are thrown out at each blast. As the noise of the explosion rumbles through the mine, there is a perceptible tremor of the rock, showing the necessity for good pillars. The smell of gunpowder smoke is at times rather disagreeable.

Dynamite is not used as its fumes are suffocating and injurious to health. There seems to be no reason why gun cotton, which is altogether unobjectionable in this respect, should not be used.

In some mines the salt is worked out in regular blocks. For cutting blocks the working surface has to be chosen parallel to the plane of stratification. If the plane of stratification is not clearly seen in the salt itself, it will be made evident by the position of the strata above and below it. At present, at Wieliczka, blocks are cut from the mine, at an extraordinary depth, by means of circular saws worked by compressed air. These saws, attended to by a single workman, cut square figures in the wall of rock, noiselessly and rapidly; wedges driven into the bases of the figures subsequently remove the blocks. In the Transylvanian mines the salt is cut with chisel and hammer into long blocks, about one foot in diameter, which are detached from their beds by blows upon their upper surfaces. Each block is then broken into smaller ones, called bolts, for market. The workmen are very accurate in their measurements, and the blocks are all nearly alike in weight. In the "Mayo" Mines, blasting is employed in some parts, and block making in others.

Short handled hammers, with heads like picks, weighing 6 lbs., and wedge-shaped chisels, are used for extracting blocks. The blocks are cut 13 inches square and 4 inches deep in the face of the rock; a pointed iron wedge is then driven in at the base, which causes the slab to separate. An average workman will get from 16 to 20 blocks a day.

In some French and German mines water is used for cutting out the sides of the galleries, and the centres are afterwards blasted away and removed in blocks. This requires first a good supply of fresh water at a convenient elevation, and second, some means of draining it out of the

mine. It is often wasteful, as the escaping brine carries off much salt, and a certain amount of ordinary mining work has to be done to prepare channels for the water which is to dissolve the rock. This system is followed in the Jura; but there the escaping brine is afterwards evaporated by artificial heat.

In ordinary rough mining, the masses of salt thrown out by the blast, are broken up into small pieces, and loaded on half-ton trollies, which run on rails to the bottom of the shaft. These trollies are often drawn by horses. At the bottom of the shaft, the salt is transferred to a tub, which is wound up by a steam windlass. At the pit mouth, the salt is dealt with according to its quality. At Carickfergus, where the salt, though pure, is much discolored by clay stains, a part, for home use, is ground down in crushers, and the rest sold for agricultural and chemical purposes. Cheshire rock salt, though very pure, is likewise only used for chemical works, manure, and for cattle. For the latter, blocks are cut from the roof of the seam, at a place where it is specially well crystallized.

Besides mining, properly so called, salt deposits are often worked by solution. At Ischl, a cave is first formed with pickaxe and blasting powder, water is then let in to dissolve the salt. When this water is saturated with salt, it is pumped off to boiling houses, which are at some distance, and there the salt is boiled out of it. At intervals the cave is pumped dry; the miners then descend, clean it, and break fresh blocks into it; after which it is reflooded. When two such caves, or chambers, approach each other, and there is fear of the partition walls dissolving—the miners descend and plaster the threatened wall with a thick paste of clay and ground rock, which stops the further action of the water on that side.

In Cheshire there are two beds of rock salt, in the Triassic Marl. The upper bed, 75 feet thick, is from 120 to 180 feet below the surface; the lower, 105 feet thick, is separated from the other by about 30 feet of hard marl. The lower bed only is worked as a dry salt mine. The great bulk of Cheshire salt, all the eating salt, is obtained from the upper bed by solution. At many places, springs of saturated brine ascend from the mines. At other places, water is let into rough excavations in the mine, in which blocks of salt are left pell-mell, and the salt is dissolved. The saturated brine, which sinks to the bottom, is then pumped up through tubes reaching into the lowest part of the cave. At Wimpfen, fresh water, to dissolve the salt, is allowed to flow down the outer case of the double tube in which the pump works, so that brine is forced up the inner tube, or pump, a considerable distance, by hydraulic pressure. In the 1,200 feet lift, the pumps only work down to 200 feet, as the brine is raised the first 1,000 feet by hydraulic pressure. The saturated brine obtained from salt mines, in this way, is drawn off to boiling houses where it yields its salt to artificial heat. The process will be described in the Chapter on salt springs. Its object is to convert the rock salt into refined powdered salt for table use, and into the other varieties of clear, small-grained salt, for which there is a distinct demand in commerce. Rock salt, though really very pure, containing in Cheshire 98 per cent. of sodium chloride, is always more or less colored, and will not powder into the brilliant white salt to which we are accustomed. It is, however, as a general rule, finer in quality and in appearance, than ordinary bay salt. There is a serious disadvantage attending the working of salt mines by solution. As the subterranean courses gradually extend into each other, and enlarge, without pillars to sup-

port their roofs, subsidence of the ground above occurs. It is impossible to control the solvent action of water, underground, so as to provide for the due support of the roofs by pillars. By shifting the works, before they become unsafe, an accident may be for years delayed; but in the long run, accidents will be more and more liable to occur. Signs of subsidence have been long noticed in Cheshire, the head quarters of brine pumping. In the streets of Northwich hollows have formed, and the houses on either hand are cracked and out of the perpendicular. In December 1880 an accident occurred near that town which has drawn serious attention to this subject.

The following is the account of this "landslip," as it is called, furnished by the *Daily News* Correspondent on the spot, December 13, 1880:—

* * * *

Further disturbances of the surface of the land near Northwich are reported. Platt's Hill Rock Salt Mine, 15 acres in extent, has been entirely filled with water, and can never again be worked as a rock salt mine, the water in the shaft having risen to a height of 80 yards. Fears are entertained that several other rocks salt mines in the neighbourhood will be inundated, and a careful watch is being kept and precautions taken. Another great chasm has opened during the night, close by Messrs. Ashton and Son's salt works, and within the area in which the principal part of the disturbance has already taken place. The roar caused by the sudden collapse of the ground was heard at a considerable distance, and it is fortunate that it did not take place in the day time, as carts and horses had been busily employed on the spot in the endeavour to repair the damage previously done. The new opening is a precipitous, goblet-shaped chasm, some fifty feet in depth, and some 30 to 40 feet across. The whole of the neighbouring ground is cracked, and shows signs of tumbling into the opening. But in fact the whole of the land thereabouts looks as if an earthquake bad taken place. Great rifts and cleaving, and bodily dropping of the surface by steps are everywhere apparent; the surface is loaded with mud from the geyser-like action which has taken place.

A great pit, known as Ashton's hole, which is over a disused rock salt mine, has lowered many feet, its crater-like banks being loaded with débris, and its waters having a peculiar and not unpleasant pinkish hue, which speaks of the ebullitions and disturbance which have taken place. Attempts have been made to repair the brine pipes leading from the pumping shafts to Ashton's works, but the opening of the chasm on the Dunkirk road left them suspended in mid air, and the communication was again stopped. Five salt works have their supply of brine thus cut off, and have stopped working, and three others have suspended operations owing to the brine having been made too muddy for use. It is feared that the dilution of the brine will seriously affect its use for saltmaking purposes, but as the Platt's-hill Mine, although it had become dangerous, was by no means worked out, it is just as likely that when the water has had time to dissolve the salt, the supply of brine to the works will be greater than ever. Should the flooding extend to Messrs. Fletcher's Mine, which is said to be the largest in the world, very serious consequences would ensue, as this mine extends for a very great distance under extremely populous districts surrounding Northwich. The subterranean effects of the great engulfment of surface waters which has taken place may be estimated by the fact that the neighbouring brine beds have had their levels raised 76 yards. The catastrophe is already of large dimensions, and must be productive of great losses, but the apprehensions it has created in the neighbourhood are if possible worse, as the sinking of buildings which is always going on more or less in Northwich will be greatly accelerated.

It appears probable that in Cheshire, the roof of a lower or dry mine is sometimes partially dissolved by percolation from an upper or wet mine, so that when the upper mine caves in from the causes noticed, the roof of the lower mine gives way also, permitting the surface soil to sink through, forming an inverted cone. Such crater-like cavities, 70 feet deep by 150 or more broad, were often noticed.

Frequent applications have been made to Parliament to stop brine-pumping in parts of Cheshire. The subsidence of the streets in Northwich has given rise to curious law-suits on the part of house-owners against the Local Board.

It appears that the Local Board is charged with keeping the streets level: but the streets have been subsiding for 150 years. House-owners go on building houses on the site of houses rendered useless by subsidence. They build their houses on a strong wooden framework, so that they can be raised, bodily, to the common street level, in case of subsidence. The streets were levelled up in 1870, 1872, and 1876, yet the subsidence goes on still.

It is said that the collapse of salt works, destroyed by water, is seldom attended with loss of life, as the people are forewarned by previous indications of the threatening disaster.

Ordinary salt mining, properly conducted, seems to be well nigh free from danger of any kind. Explosions of gas, are almost unknown, and fire damp does not appear to have been noticed, except once at Northwich and once at Meddow Bank, in Winsford, and then in small quantities. Duma's experiment of dissolving a portion of rock salt and gathering the bubbles of gas which burst from it, proves however, that a good deal of inflammable gas may at times exist in salt. The miners in the Marston Mine have, on several occasions, struck into hollows in the rock salt filled with inflammable gas. In December 1880, such a cavity was tapped. This gas takes fire at the candle, and burns away like paraffin oil, but without any explosion or poisonous effect upon the atmosphere. In 1745 a curious phenomenon occurred at Wieliczka. A sort of subterranean storm burst open doors, tore down beams, overthrew the workmen, and finally, as it passed out of the mouth of the shaft, wrecked the buildings which overlooked the pit. From its sudden violence, this storm appears to have been in reality an explosion of some kind.

The air of a salt mine is generally very dry and healthy.

Salt miners enjoy excellent health. They often work up to 80 years of age at light jobs. At the Marston Mine three generations of the same family may be seen at work at a time. Pulmonary consumption is unknown in the mines, as far as I could learn. The mines preserve a constant and agreeable temperature, being comparatively cool in summer, and warm in winter; the thermometer seldom falls below 55° F., or exceeds 75° F. except in the "Mayo" Mines where the highest temperature is 80° F. The darkness is extreme, and scarcely relieved by the tallow dips now used. At first, a stranger entering a salt mine sees nothing but the dull flame of his candle, framed in impenetrable black. After an hour or so, when leaving the mine, he is astonished to notice at the foot of the shaft a number of objects that he could not see there when he descended it; but they are still obscurely seen. It is probable that the electric light will, in time, remedy this evil. I have seen salt mines illuminated by artificial fires. The effect disappointed me. The salt, naturally dull and begrimed with smoke, did not yield any striking reflections. Gun cotton and the electric light would, by doing away with the smoke of gunpowder and of tallow candles, improve the appearance of the mine.

Many striking descriptions have been written of the marvellous interior of the Wieliczka Salt Mine, the largest in the world. It is a city 900 feet underground, having its high roads, extending for 50 miles or more, houses, even villages, horses and men, deep in the bowels of the salt. The building material is rock salt. It is well lighted and much of the rock salt being of the best, or transparent quality, it presents in many places very beautiful illuminations, and color effects. The chapels and statues of salt have been already referred to. It has been worked since the year 1251, or for the last 630 years, and is practically inexhaustible.

The following analyses of rock salts from different mines, conveys at a glance a good idea of its composition and general purity.

ANALYSES OF ROCK SALT.

	Cardona.	Wielickza.	Hall.	Cheshire.	Mayo Mine.	Holsten, U. S.	Ouled Algeria.	Lahore.
Sodium Chloride.	98·55	100·	99·43	98·30	93·04	99·55	98·89	92·9
Potassium ,,	...	...	trace.	...	...	...	...	..
Calcium ,,	0·99	...	0·25	...	0·42	trace.	...	...
Magnesium ,,	0·02	trace	0·12	0 05	0 71	...	1·11	1·76
Calcium Sulphate.	0·04	...	0·20	1·65	0·69	...	...	2·61
Magnesium ,,	...	...	...	...	...	...	...	2·64
Magnesium Carbonate.	...	...	...	...	...	0·45	...	...
Insoluble ...	...	...	...	...	...	...	...	0 12
Water and loss	...	...	...	...	5·14	...	...	...
	99·60	100·	100·	100·	100·	100·	100	100·03

CHAPTER VI.

HYGIENE.

Salt, for physiological reasons, which will be presently referred to, is almost universally used as a condiment. There is a craving for it amongst all people who live on cooked food. Primitive tribes, who live like wild beasts on a purely carniverous diet, are naturally not in want of it: for they get enough of salt in their food. Raw or partially broiled meat contains, as we have already seen, enough salt to season it. But for those who boil their meat, or eat grains or vegetables, salt is a necessity. Salt, when taken in the mouth, is at once perceived by its peculiar saline taste. Taken alone, it is hardly palatable; but with food it has a most agreeable flavour. It blends freely with almost every kind of food and developes and improves the taste of most plain foods. 'An egg without salt' is a saying that has wide application to disagreeable things, although the albumen or white of egg contains a little salt. A diet that would be intolerable without salt, becomes through its use the chief support of a nation. This is a very striking and important matter when we consider that the great bulk of the vast stores of food with which the earth abounds would be rendered practically useless if it were not for the wide distribution, and unlimited provision of the salt required to season them. A far seeing wisdom has tempered salt to plant life, for plants are injured by it; but men and animals

are otherwise amply provided for. In consequence of cheap salt, nations and people flourish, who would otherwise perish in the midst of plenty. It has passed into a joke in Ireland, that the people live on "potatoes and point," that is on potatoes and salt, pointed at a herring by way of relish. On this diet the Irish poor still subsist in many of the Western districts. In India, Burmah, China, and most other Eastern countries, the majority of the people live on rice and salt. In Europe, wheaten flour and salt, in the shape of bread, is the staple food. And everywhere, it may be said, the poor are indebted for continued existence to these same elements of food, the starchy and the saline, one essential to the other.

On the Continent, where vegetables are much eaten, salt is used even more freely than in England. The poor man's vegetable soup would be nothing without it. It is also used in a way seldom seen in England, that is with fruit, such as the pine-apple, melon, orange, pear and strawberry. It is said that it brings out the flavour of fruit. It is quite a usual custom in France to eat melons with salt. This, however, is a luxury, and like the use of black coffee and brandy after meals, more a matter of habit than anything else.

In the mouth, salt acts as a stimulant to the gustatory nerves, and causes an increased flow of saliva; which flow has an important action in promoting the digestion of food. It also prevents foul breath, by preserving the food, engaged in the teeth, from decomposition. In the stomach, a portion of the salt is decomposed into hydrochloric acid and some soluble sodium salt. The former is set free to perform the important office of stomach digestion, whilst the latter is absorbed to preserve the alkalinity of the blood. The remainder of the salt, ingested, continues as sodium chloride.

A part of it, unchanged, accompanies the food throughout its passage and is found with the excretions. It is probably the office of this part to prevent putrefactive decomposition, and the evolution of noxious gases in the intestine. Another part is absorbed, and appears as sodium chloride in the blood and various secretions of the body.

Acting either through the blood, or directly on the food in the intestine, or in both ways, salt is essential to the hystogenic changes which the organic constituents of the food undergo. It is present in considerable quantities in the salivary and gastric fluids, and in chyle and lymph. It has marked solvent properties on albumenoid substances, as albumen and casein. Globulin, a constituent of the blood discs, requires a little for its solution in water: so also myosin, the proteid constituent of dead muscle; and vitellin, the modified albumen of yolk of egg. The experiments of Professor Zabelaine prove that the presence of salt in the food augments the quantity of iron taken up by the body. It is the solvent of the fibrine in the blood; and its relation to the fibrine determines the coagulability of the latter; a matter which has been frequently noticed in febrile conditions of the body.

The most important function of salt seems to be the formation of hydrochloric acid, the acid of the gastric juice. The gastric juice consists of water 994·40 parts, sodium chloride 1·46 parts, acid hydrochloric 0·20, calcium and potassium chlorides 0·61, phosphates 0·12, and pepsine ferments 3·19. Of 2·39 parts total inorganic constituents, the chlorides form 2·17 parts. When we consider that about 15 pints of this secretion are formed in the body daily, the importance of a due supply of sodium chloride will be evident. It also stimulates the mucus membrane and the muscular fibres of the whole alimentary tract.

The absorbed salt preserves the balance of density in the fluids of the body; it controls the processes of effusion and absorption; in a word it is active in promoting normal manifestation of endosmose and exosmose. By maintaining the density of the blood plasma, salt conserves the morphological elements of the blood in their usual condition. Salt is contained exclusively in the serum, or watery part of the blood; there being none on the corpuscles. The serum of the blood contains 5·546 parts sodium chloride per 1,000; besides carbonates, phosphates, and sulphates of soda, amounting together to another 2·084 parts per 1,000. *(Schmidt.)* Salt serves as a reservoir of these sodium salts and of chlorine in the system; 100 parts of the ash of the blood contains 54·7 parts of sodium chloride. *(Kirke.)* Next to the blood, muscle contains the largest amount. According to Enderlin, the ash, left after the incineration of ox-flesh, yields about 46 per cent. of chlorides of sodium and potassium; which, as this ash constitutes 4·23 per cent. of the dried flesh, would give 1·94 as the proportion of salt in the latter; and taking the dried flesh as 28 per cent. of the fresh muscle, the remaining 77 parts being water, the proportion of salt in fresh meat would be 0·44 per cent. Cartilage comes next to muscle as regards the percentage of salt, 11·2 per cent. being found in the laryngeal cartilage.

The following is the percentage of sodium chloride in the liquid, solid residue, and ash, of some animal fluids:—

	Liquid.	Solid residue.	Ash.
Human blood	0·421	1·931	57·641
Serum of Pus. (Nasse)	1·260	11·454	72·330
Mucus (Nasse)	0·583	13·100	70·000
Human Bile	0·364	3·353	30·464
Chyle	0·531	8·313	67·884
Lymph (Nasse)	0·412	8·246	72·902
Saliva	0·153	12·988	62·195
Human milk	0·087	0·726	33·089

Sodium chloride enters into some important chemical reactions in the blood, whereby the corpuscles receive a supply of their appropriate salt. Common salt and phosphate of potassium undergo a double decomposition in the blood, resulting in the formation of potassium chloride, which is found in the red blood corpuscles and in muscle, and in sodium phosphate, which is found in the bile. These salts have an important purpose in the respiratory process. Salt probably has an antiseptic action on the air passage, preventing the decomposition of its secretions, which are prone to putrify—mucus, pus, inflammatory exudations, and tears, are all saline. It is without doubt an anthelmintic, and prevents the lodgment of worms in the intestines. Probably also it checks the development of parasites in the tissues.

It is stated in Lord Somerville's address to the Board of Agriculture, that the old laws of Holland "ordained men to be kept on bread alone, unmixed with salt, as the severest punishment that could be inflicted upon them in their moist climate; the effect was horrible: these wretched criminals are said to have been devoured by worms, engendered in their own stomachs." And Mr. Marshall mentions the case of a lady, who had an incontrollable aversion to salt, who was in consequence plagued with worms all her life. (Aitkin's Elements of Physiology.)

Schleiden, Das Salz, page 187, says, that salt influences the general cell formation of the body, promoting it, and its use therefore increases the weight of the body. He attributes the superior quality of English prize cattle to the use of salt. Boussingault, however, (Ann. de Chimie, 1847-48-49) found that one or two ounces of salt a day was not sufficient to influence the production of milk or fat. Dr. Rattray, R. N., who studied this question in the tropics, believes that an exclusive salt meat diet *in the tropics*, leads

to loss of weight. He found that 81 per cent. of the men, experimented upon by him, lost 4 lbs. in weight at the end of three months. (Proceedings, Royal Society, vol. xix, p. 302.) This refers to excess of salt combined with heat. Salt is nature's antiseptic, in case of wound or injury, preserving the effused serum, or pus, at the surface of a wound, from putrefactive decomposition. It will have been observed that these fluids are especially rich in salt. In a pure atmosphere, pus decomposition, with ordinary cleanliness, does not take place; but under the extraordinary atmospheric conditions to be found in large towns, especially in town hospitals, the salt of the blood is powerless to arrest septic change.

In one or two morbid conditions, that are very common, there has been found a deficiency of salt in the system. In scrofula, for example, there is not only a deficiency of salt, but there is a real aversion to it, which has to be overcome in the treatment of that disease. In typhoid fever, there is a diminution of salt, accompanied by an increase of fibrine. As sodium chloride is the chief solvent of fibrine, the two things are coupled together as cause and effect. So also in various inflammatory conditions of the system—formerly recognized by the buffy coat of blood, drawn in venæsection—salt is deficient, and fibrine in excess. It has been noticed in fever cases, that as the febrile symptoms increase in severity, sodium chloride diminishes in the blood. Fever patients for this reason prefer salt to sugar. The relations of salt in the blood, to disease, have not as yet been properly studied; but there can be no doubt that in the febrile state, which accompanies most diseases, it plays an important part.

Gouty persons are probably the only ones who suffer from indulging too freely in salt. Although, in the majority of persons, excess of salt is carried off by the excretions, in gouty people there is good reason to fear that it is converted into

urate of soda, an insoluble salt, which cannot therefore be execreted as such, and consequently accumulates in the system. This urate of soda is the material of which gouty concretions, or chalk stones, are formed; and it is the presence of this morbid product in the joints which gives rise to pain and what is called a fit of the gout. Nevertheless, even gouty people are benefited by the local application of brine to the joints, as hundreds will testify, who have tried this mode of treatment at Northwich.

The amount of salt required for daily consumption to maintain the body in a condition of health, varies greatly with the dietary, as salt is already contained, more or less, in most articles of food, but it would probably average half an ounce a day. Dr. H. King, (Manual of Hygiene) says, "Thus 100 grains are, perhaps, sufficient in jails where the staple food is wheaten flour, while at least twice this quantity will be required with a rice diet. It is scarcely possible to lay down a general rule on the point except this, that excess can do no harm, while deficiency must be injurious, and that it is a mistake to economize by reducing the ration of so cheap and necessary an article of food as salt at the risk of impairing health." "In the French Army, the allowance of salt is 0·5 ounce; in the Navy, 0·77; in the Russian, 1·59; in the English about 0·25. Numerous experiments made in England and France have shown the amount of salt daily excreted under ordinary circumstances to range from 0·4 to 0·6 oz."

Parkes gives the following percentages of sodium chloride in the undermentioned articles of food :—

	Sodium chloride. p. ct.		Sodium chloride. p. ct.
Fresh Beef	0·310	Eggs	0·15
Wheat	0·041	Milk	0·041
Potatoes	0·013	Bread	0·5
Cabbage	0·156	Peas	0·044
Cheese	3·45	Butter (added)	0·5 to 2·0

Fresh Fish contains about 2·2 p. ct. of salt.

Food grains contain less salt than flesh meats in the following order: barley, oats, wheat, rye, maize and rice. In the chapter on agriculture, further information on this point will be found.

The amount of crude salt to be allowed in calculating diets will therefore vary with the nature of the other foods; but half an ounce in 24 hours will be a low average. Parkes says, that "463 grains of chloride of sodium, can be absorbed by most persons; but if a larger quantity be taken, the excess usually appears in the fæces."

Salt is found in nearly fixed and definite proportions in the various fluids and tissues of the body. It is very probable that excess of salt is always carried off in the excretions, and that pure chloride of sodium, consumed in excess, under ordinary circumstances, has no injurious effect on the system. On the other hand it ceases entirely to be excreted if it falls below a certain quantity, showing that a certain percentage of it is essential to the system. Seafaring men live in an atmosphere of salt, without injury to health. In the Mines of Cheshire the workmen breathe air loaded with salt dust, without other inconvenience than that caused by the irritant effects of the dust. Many men in Wieliczka have been at work in the salt mines for 40 or 50 years, and have enjoyed excellent health. It is a noted fact too, that horses thrive in the mines, though, once sent down, they never again see the light of day. Horses which are in a sickly condition, when first admitted to the subterranean galleries, rapidly improve in condition and gain strength.

Sailors ignorantly attribute scurvy to the use of salt provisions. It is well known that scurvy is the result of a deficient supply of the organic acids, the salts of vegetables and fruits, and the potash salts of fresh meat; and that it results equally from any diet which withholds these substances.

In some places, where impure sea salt is consumed, sodium chloride gets the credit of producing certain bowel and skin complaints, which are caused by the magnesium salts, sulphate and chloride, with which it is mixed.

The adulterations of common salt seldom attract attention unless they produce injurious results. Some of them however are worth noting. Sand and dirt are the most common in India. They are found chiefly with bay salt; and are for the most part derived from the pans in which the salt is made.

A certain amount of sandy soil is occasionally added to the salt, by the vendor, to increase its weight and bulk. Discoloured bay salt lends itself to this practice, as it is difficult to detect the adulteration. Its effect upon the system will vary with the nature of the soil. It may be *nil*; or it may be very injurious from the presence of organic matter of a poisonous nature in the soil. There is no need to dilate on the different organic poisons which may, in this way, find an entry into the system! Sulphate of magnesia is not uncommonly found in bay salt of inferior descriptions. It is largely present in sea water, and separates from it with common salt, if the process of manufacture is not carefully controlled. It gives the salt a purgative character, and this often leads to its detection. Magnesium chloride is always present, more or less, in bay salt, even in that which has been well refined; occasionally it exists in such quantities as to produce irritant effects upon the mucus membranes and skin. It may give rise to watery purging and eczematous eruptions. Gypsum should be also mentioned as an adulteration, more particularly of ground rock salt. Alum is found in the artificially evaporated salt of brine springs. It is employed for the purpose of clarifying the brine. Its astringent effects are well known. The oxide of arsenic

must be added to this list. The attention of the French Government was attracted some years ago to outbreaks of sickness produced by the salt of Paris and Meaux. M. Guibourt, who was deputed to investigate the cause, discovered oxide of arsenic in the salt, and this was confirmed by M. M. Latour and Lefrançois, who found that the arsenic sometimes amounted a quarter of a grain to the ounce. The most deleterious of all the adulterations of salt is the iodide of sodium. In the year 1829 several outbursts of epidemic diseases in France, of a very severe character, were traced to this source. The symptoms were pain and distension of the abdomen, with nausea, vomiting, slimy and bloody purging, inflammation of the eyes, puffiness of the face, and œdema of the legs. In some districts of the Marne, one-sixth of the population was attacked; and in two parishes alone, 150 people suffered. M. Sérulas, who was deputed to examine the suspected salt, found in it about one per cent. of the sodium iodide, and M. M. Boullay and M. Delens, who tested his analyses, confirmed their accuracy. Previously, M. Barruel, a French Chemist, found sodium iodide in salt which he was using in the preparation of an experiment for Orfilla. He also found it in two specimens of salt taken from grocer's shops in Paris.

Bromides also occur occasionally as impurities in sea salt. The "Bulletin Universelle" for 1831, draws attention to the inferiority of the French salt at that time. The salt used at Frere Champenoise, and that neighbourhood, having induced violent colic, accompanied by swelling of the face, in many of the inhabitants. It was examined by M. Cosmenie and found to contain bromide of sodium, as well as the iodide.

Notwithstanding what has been said as to the hygienic value of salt, there are some people who profess to dislike

it, and who do not make use of it at table. Their aversion may be the result of *idiosyncracy*—a word which covers our ignorance of the cause,—and be genuine, or, as in the few cases I have met with, the prejudice may be genuine whilst the aversion is only apparent, and this I believe is the general rule. In the cases that have come under my own observation, the peculiarity consisted in a disinclination to the use of salt at table. No aversion was shown to ordinarily cooked foods. Indeed, people who believe themselves to be thus affected are often *bon vivants*: and appreciate highly a good *menu*. They overlook the fact, however, that all cooks, from the plain to the *Chef*, use salt largely in the kitchen. None but housekeepers know the expenditure of kitchen salt. Good cooks use it so freely, that they leave very little to be desired in the way of "seasoning salt" at table. In Paris, justly renowned for its cooking, salt is often untouched at table, as the "artist" in the kitchen has attended properly to the seasoning. It is just possible that in England we may yet reach such a pitch of civilization that cooks will send us food, ready to be eaten, and the use of table salt will be relegated to the books of the antiquary. However that may be, any one who eats ordinary cooked food, at home or abroad, eats salt, and the objection to eat more at table does not constitute an idiosyncracy. It has been occasionally pointed out, as evidence that the hygienic value of salt is over-estimated, that not only individuals, but even whole tribes of men, are averse to it. The tribes referred to, however, are in a very primitive condition, as regards their food: and their want of the salt instinct is either referrable to their carnivorous habits, or to the presence of atmospheric salt; or in many cases to both these causes.

Admiral Von Wrangel (Expedition to the Polar Sea, pp.

76, 377,) says, that the natives never used salt and even disliked it. But they lived on an exclusively animal diet of flesh and fish captured from the sea. Mr. Galton mentions that the Damara's natives never eat salt. American Indians, eating their food nearly raw, (never boiling it), lose none of the salt. Mr. J. S. Kohl says, that the Ojibbeway Indians have a perfect aversion for salt; but they use wood ashes, containing soda and potash salts, with their maze cakes. (Kitchigomi, p. 322.) M. Catlin states that none of the Indian tribes, on the Upper Misouri, use salt, though their country abounds in salt springs and salt incrustations, except the frontier tribes, who use vegetable food. He also noticed that during a cholera epidemic, the frontier tribes suffered severely: whereas whenever the cholera came to tribes living exclusively on meat, without the use of salt, its progress was suddenly stopped. (Letters and Notes on the N. American Indians, vol. ii, p. 258.). This last fact, about cholera, is taken as an indication of the injurious influence of salt; but it is susceptible of quite a different interpretation. It seems far more probable that the cholera stopped, owing to the salt atmosphere of the interior of the district, which also relieved the natives from the necessity of eating salt. Sallust (Jugurth, 87,) says, that the ancient Numidians took milk and game without salt. It appears from Azara. (Voyage dans l'Amerque Merid, vol. i, p. 54,) that in several parts of tropical America, salt was unknown before the arrival of Europeans. Schleiden, Das Salz, says, p. 11, that the inhabitants of Spielman's Bay and Humboldt's Bay, New Guinea, as also those of New South Wales, were unacquainted with the use of salt. Also, page 12, that the Bedouins in the interior of Arabia do not use salt. Adolf Von Werder explains the special case of the Bedouins by the very probable supposition that they have very little

water in the desert and are obliged to take every precaution to avoid thirst. All these citations prove that primitive man, as is related in the 1st Chapter, could and did exist without salt; that the people who are cited as not using salt, are in the same state of civilisation as regards food as our first ancestors; and that all we have to do if we wish to dispense with salt is to give up the pot and imitate savages in our diet.

But were we deprived of salt, without the refuge of a rich meat diet accompanied with fruits, as some people have been, our lot would be a very painful one. Mungo Park says, "I have myself suffered great inconvenience from the scarcity of this article. *The long continued use of vegetable food creates a painful longing for salt that no words can sufficiently describe.*" David Livingstone mentions how he felt the want of salt as a privation, when living on a vegetable diet in the interior of Africa; and that he was quite struck with the agreeable saltish taste of meat whenever he could get any. (Travels in Africa.) Father Low, a Jesuit Missionary, who died of exhaustion in the interior of Africa in the summer of 1881, more than once attested to his sufferings from the want of salt, about the only complaint which appeared in his letters. (*Tablet*, May and June 1881.) It is probable that want of salt in the interior of Africa has much to say to the fatality which so often overtakes European explorers there.

This is the place to notice, as far as need be done, the work of R. Howard, M.D. (See Bibliograply.) He has written two treatises to prove that salt is a perfect curse to man. His statements and arguments are based on eccentric interpretations of scripture. It will be sufficient to mention some of them. He says, that it is his object to show that before the fall of nature, man did not eat and drink, but was nour-

ished by a delicious atmosphere. "Salt was the forbidden fruit." "It is called in scripture the abomination of desolation." "It breeds worms and vermin of all kinds." It is one of the chief causes of mental insanity. It is a cause of cataract in the eye: a common cause of pulmonary consumption or decline. It deprives food of its nutritive qualities. It is distinctively productive of disease amongst animals! &c.

Closely connected with the appetite for salt, which is after all the expression of the craving of the tissues and fluids of the body for an element necessary to their existence, is the condition of the atmosphere as to salinity. Near the sea, salt exists in the atmosphere in minute quantities. The wind that lifts the spray from waves, carries particles of salt for miles on its course. We shall see, hereafter, that salt storms have affected vegetation full seventy miles from the sea. But storms are not necessary to the diffusion of sea salt in the atmosphere. In the ordinary course of evaporation from a rippling sea, molecules of salt are thrown upon the air, and caught up to its higher regions. Direct experiments prove that in evaporating sea water on a large scale, in the laboratory, a little salt comes over, mechanically disengaged from the bubbling surface, and borne off by the rising steam. At Nauhaim, in Germany, a glass plate exposed on a high pole, 600 feet from the salt works, was found covered with salt every morning, as soon as the moisture on it had evaporated. This atmospheric salt is in a very fine state of division; it enters the blood through the lungs, and as far as it goes, tends to diminish the ordinary appetite for salt. As has been noticed, in considering the influence of the sea on climate, it is this finely divided salt which causes mists and clouds at sea, by affording a nucleus for the condensation of watery

vapour. A little salt may therefore be detected in meteoric waters by chemical tests; though they are, according to all ordinary standards, fresh. It is related in Phil. Trans. No. 289, pp. 1530-35, that after the salt storm of 1703, a Mr. Lewenhock, of Delft, in Holland, found crystals of salt on his window, after rain. This shows that rain may occasionally bear appreciable quantities of salt. The precise action of atmospheric salt has not been studied. No doubt it plays an important part in the health-giving influence of sea board climates; in the aseptic condition of the atmosphere; in the arrest of plagues, which appear to be limited by comparatively narrow seas; in the stimulation of vegetable life; and in the formation of clouds. Dr. Gillebert d'Hercourt's observations, made at Monaco, on the Riviera, the favourite health resort of consumptives, show that the atmosphere there is impregnated with saline particles, from what he calls sea pulverization, to a height of 60 or 70 metres. He notes that this salt stratum of air is carried far away inland, if not obstructed by high mountains. (Quart. Jour. of Sci., vol. vii.)

In salt mines, in the neighbourhood of salt swamps, and plains covered with efflorescent salt, the salt appetite of the dwellers therein would be naturally modified, as salt makes its way into the system through the mucous membranes of the eyes, nose, mouth, and respiratory passages.

Medical.—The use of salt as a medicine was fashionable at one time, though it is not so at present. It does not follow, however, that it has been abandoned as useless. It has slipped out of sight, being eclipsed by the discovery of new and powerful drugs, having the same therapeutical effects, but which act more energetically. More attention has been given to the use of salt in medical practice, abroad, than in England. In France several treatises have been published

on this subject, relating both to medicine and surgery. Salt, still, however, retains a certain value as a household remedy. In large doses, as a table-spoonful, it is a good emetic. It is an antidote to poisoning by lunar caustic or nitrate of silver, which it breaks up at once into silver chloride and sodium nitrate. In moderate doses, as a desert-spoonful, repeated two or three times, at intervals, it acts as a purgative. It is a hydrogogue purge, that is it causes watery discharges by altering the balance of endosmose and exosmose. It is in common use by the poorer classes of the natives of Pondicherry as a purge. In Ireland many people drink a mug of salt water in the morning to regulate their bowels. Its anthelmentic effects are well known. Given in tea-spoonful doses, once or twice daily, it is often successful in expelling round worms from the body. A strong solution of salt, used by way of enema, is most efficacious in getting rid of threadworms. Salt baths, salt water embrocations, aud saline douches, are familiar ways of treating sprains and chronic joint affections.

Bags of hot salt, retain heat well, and are useful applications where heat effects are required.. They have been especially recommended in the common form of sore throat. The usual practice in such cases is to enclose hot salt in a clean stocking, which is then tied round the throat. Salt is also used in gargles, in ordinary cases of sore throat, in the proportion of a table-spoonful to a pint of water; to this gargle a table-spoonful of vinegar is often added. Salt is used, occasionally, with excellent effect, as a remedy for toothache. It should be applied, *finely ground*, to avoid mechanical irritation, a pinch at a time, to the gum, *outside* the diseased tooth. It acts as a counter irritant, and derivative, and causes a free flow of saliva. Salt has been used in cholera to correct the deficiency of saline matter in the blood.

In this direction its use has not been attended with much success. Salt water douches and embrocations are much used in the treatment of weak joints, sprains, &c.

Dr. Boddy (History of Salt), says, that in cases of nausea without vomiting, half a tea-spoonful of salt in a little water, sometimes effects a cure. He also says, that the same remedy will give speedy relief in violent attacks of colic, and recommends it when no other remedy is at hand. Also in hœmorrhage from the lungs, when the usual treatment fails to give relief. "When applied to a cut the bleeding ceases."

In 1862, Dr. Scelles published a report, "*The efficacy of salt in combating intermittent fever among the peasants of the fenny districts,*" for which he was awarded a medal by the *Academy of Medicine*. He says, that common salt is almost as indispensable to men and animals as the air they breathe: it facilitates digestion; aids powerfully hematosis (or oxidation of the blood); and assimilation. He gave it in doses of one-third to one ounce in 35 to 50 ounces of liquid, such as soup, coffee, etc., and in many cases the fever did not return. Professors Piory, Velpeau and Lecann, reported upon this paper. Professor Piory states in his report that salt acts in some cases better than Quinine, and in others the contrary. He thinks it might be given in combination with Quinine. Salt has also been used in the treatment of small-pox. An anonymous pamphlet on common salt as a remedy for small-pox was published by Pitman, London, 1871. It bears evident marks of having been written by one untrained in the science of medicine. The author declares that "the nature of the disease is an *abnormal fermentation or putrefaction of the living membrane of the stomach,* caused by an introduced poisonous substance, germ or atom, acting on the epithelial cells. The italics are his. As salt ingested furnishes hydrochloric acid in the stomach,

an acid which arrests putrefactive changes, and promotes digestion, he recommends it as a remedy. He mentions three or four doubtful cases, in which the salt treatment seemed to check the development of the disease. "*It caused the eruption to take the form of chicken-pox for the greater part*"! The treatment consisted of salt in solution, salt baths, and a salt meat diet of ham, salt fish, etc.! The pamphlet concludes with some anti-vaccination remarks. Salt may be, and doubtless is, useful in small-pox; carbolic acid, another antiseptic, is much used in its treatment; but there is little in the pamphlet to show that it is so, and much to prejudice the professional reader against the author's views.

Salt is a valuable remedy in surgical practice. I have used an ointment composed of 40 grains of salt to the ounce of lard, or vaseline, extensively amongst Hospital patients, as a dressing to ulcers and sores of all kinds, which required stimulation, and with the most gratifying results. I can recommend it as a good antiseptic and stimulant application, which may be continued until the sore is healed. I have also found a strong solution of sodium chloride an excellent stimulant and antiseptic injection to the cavities of old abscesses, sinuses, fistulæ, etc., requiring to be healed by stimulation.

Snake Poisoning.—Without attaching undue importance to them, one or two references to this subject, which exist, may be mentioned. Benjamin Gale, in 1765, wrote a paper, in Philosophical Transactions, concerning the successful application of salt to rattlesnake wounds. The Rev. J. Fischer, a South American Missionary, states (Am. Jour. Sci. and Art., vol. 21, p. 159), that taking the hint from Bishop Loskiell, he tried common salt as a remedy for snake bite. He writes very positively of its good effects. He writes that he has "cured all kinds of dangerous serpents' bites" "*after*

they had been inflicted many hours," by rubbing common salt into the wound, giving it also internally. Unfortunately the species of snake is in no case specified, and from the words I have italicised it is probable that the serpents were not of so poisonous a kind as they are in India, where the bite of a cobra proves fatal in very few hours. A man who would survive a snake bite *many hours* in India, would probably survive altogether under any form of treatment. Bishop Loskiell, in his *History of the Moravian Church in North America,* states that certain tribes of Indians had no fear of snake bites, relying on common salt as an antidote. So certain were they of the efficacy of salt, that "some of them would suffer a snake to bite them for the sake of a glass of rum." An Indian snake-charmer will even now suffer the same thing for the equivalent of a glass of rum in coin of the country; but it is generally believed that the snake used is deprived of its poison fangs. Salt and tamarind, rubbed into scorpion wounds, are said to relieve the pain.

In Veterinary practice, common salt is extensively employed. Many striking instances of its beneficial use are quoted in the Parliamentary papers referring to this subject. Youatt says, "It forms an efficacious aperient clyster; a solution of it has even been given as an aperient drink. Sprinkled over the hay or in a mash it is very palatable to sick horses; and in that languor and disinclination to food, which remains after severe illness, few things will so soon re-call the appetite as a drink composed of eight ounces of salt in solution. To horses in health it is more useful than is generally imagined, as promoting the digestion of the food, and consequently condition. Externally applied there are few better lotions for inflamed eyes than a solution of half a drachm of salt in four ounces of water. In the proportion of an ounce of salt to the same quantity of water,

it is a good embrocation for sore shoulder and back; and if it does not always disperse warbles and tumours, it takes away much of the tenderness of the skin." Sea water, or common salt in solution, is the favourite application of Madras horse-keepers to collar galls and saddle galls. I have often witnessed its good effects. Salt makes a good antiseptic tooth powder. Sea water is commonly used as a tooth wash and gargle by people living near the coast. The Hungarians are said to use salt in the purification of foul well waters, as did the Prophet Isaiah in the town of Jericho. In Jericho the living being good but the water bad, the Prophet Isaiah called for a pot of salt and threw it into the water to clear it, saying "I make this water healthy and pure."

Change of air to the sea side is only another form of treatment by salt. We have seen how the sea side atmosphere is impregnated with salt. The list of diseases benefited by salt air would include fever, dysentery, consumption, anæmia, liver and other complaints. Consumptives especially are benefited by warm sea air. It has occurred to me that this is owing to the antiseptic action of the salt air preventing the putrefactive decomposition of the fluids in the diseased lung cavities of phthisical patients. They suffer much from hectic fever, a form of fever which accompanies pus, or matter formations, acted upon by air. Foul air contains germs, bacteria, or bacilli, which alighting on animal fluids cause their putrefaction. A little of this putrefied fluid, absorbed into the system, lights up hectic fever, also known as surgical fever. Various reagents, as carbolic acid, kill the bacteria, and prevent putrefactive changes. They are hence called antiseptics; common salt is an excellent one. Sea air contains enough of salt to influence for good the inward sores or lung cavities of consumptive patients. Sea air, no doubt, also contains more of iodine and ozone

than town air; and it has other advantages besides, being decidedly more equable in temperature. Near the coast, the air is warmer in winter and cooler in summer than it is further inland.

It is noteworthy that at all regular salt-hydropathic establishments, the physicians in charge insist on the inhalation of salt air in the salt works, or by the sea, as the case may be.

It will not be a great digression to enquire here how it is that sailors and bathers are able to go about with their clothes wet with salt water without injury. Native fishermen and pearl divers in the East are almost amphibious; but there the sea is warm. The Welsh salmon netters, however, and the unfortunate bathing men, at the French "Bains du Mer" spend a good deal of time in cold salt water, hours at a stretch, without much suffering. It is a common expression when any one gets wet at the sea side, "It is only salt water" showing that most people believe that no ill effect will follow; though perhaps not many know the reason why. The reason is because the salts in the water retard evaporation, and prevent the great fall of temperature which there is with fresh water. The salts hold the water and arrest evaporation, altogether, at a certain point. They moreover stimulate the surface and keep the circulation going there, instead of driving in the blood, and congesting central organs.

The salt water cure is a well known expression. It refers to the extensive use that is made by physicians, especially on the Continent, of salt water baths, either marine or artificial, in the treatment of certain complaints, principally chronic skin diseases, and especially those of a parasitic kind. The sea salt so conspicuously advertised in England, is manufactured to supply this want. It is probable that

nothing can equal the sea itself for efficiency as a medical agent, owing to the complexity of its composition, and the accessory hygienic influences which surround a dip in the sea. There will be always, however, cases enough, unequal to exposure, for whom the home bath of artificial salt water will be necessary.

Apart from disease, salt water bathing is a recognised means of preserving health. Many look forward to their annual sea bathing to re-invigorate their systems and give them a new lease of life. There is a movement now on foot to bring salt water to London, in pipes, for the supply of public baths, at present supplied with fresh water.

In the Boiling house attached to the Ischl Mines, in Austria, the salt water cure is practised, and held in great estimation. Here, there are mother liquor, or *Bittern* baths, consisting of the concentrated residual brine from which salt has crystallized; also, salt vapour baths, in which the patient inhales the vapour impregnated with salt, which exhales from the steaming "crystallizing" vats. In these latter the patient gets the benefit of the application of the salt vapour to the surface of his body, as he sits undressed, suspended over the vat. He is supposed to take the baths twice daily, and to spend an hour or so after each bath, in the warm gallery attached. Salt baths are used at Homburg, to which place the mother liquors of salt manufacture are brought at some expense.

Another celebrated "salt cure" establishment is worked with great success by the German Doctors at Kreutznach, and attracts large number of visitors. The German physicians were the first to study and popularise this mode of treatment, which now takes high rank in Europe, in certain medical cases. Switzerland boasts of its salt baths at Bex, Canton Vaud, near St. Maurice; and France of its salt cure

at Salins, Dept Jura. All of these are supplied with salt water by the evaporation of brine springs, or with rock salt from neighbouring mines.

At Croisic, in Brittany, there is an establishment for the treatment of certain diseases by sea water, and the mother liquor of bay salt manufacture, which is unique of its kind in Europe. It was established at the instigation of the famous Professor Trousseau, who, recognizing the good effects of the German salt baths, was impressed with the superiority of the sea, which contains all the salts in the German springs and many other besides. Sea water is in fact one of the most powerful mineral waters we know of. It acts, in the first place, as a bath, cleansing the skin, and its action is, in this respect, very energetic. It was used as a cosmetique by the Roman ladies; and the German ladies have the same opinion of it. (*Schleiden, Das Salz*, p. 311.) It acts next by compelling exercise. Every one knows, swimmer or no swimmer, that considerable force and activity are required of any one taking a dip in the sea. There is, thirdly, its remarkable stimulant effect upon the cutaneous system, due to the salts it contains; this permits of a long dip, and promotes the functional activity of the skin. Fourthly, the effect of cold or shock, as it is called, upon the nervous system, varying with the mode of entering the sea. Fifth, the *massage* or impulsion of waves, which is thought a good deal of on the Continent. And sixth, the reaction, which is always well pronounced after a sea bath, if it has not been too prolonged. Now, these effects are, in the open sea, even as regards the healthy adult swimmer, liable to great variation. The temperature, both of the atmosphere and of the sea, undergoes marked changes, which influence the time of the bath, or length of exposure to the salt solution, the shock, and the reaction. And the sea itself presents still

greater alterations; at one time calm, and measured in its movements, at another violently agitated and knocking the bather about unmercifully. Delicate persons, and those in bad health, cannot bathe daily in the open sea; they have to pick their days, and thus lose much of the benefit of a sea side residence. To obviate these inconveniences, the Croisic administration have established a *piscine*, or enclosed and covered sea bath, in which the tide rises and falls, and which is warmed artificially to a constant temperature. This is of the greatest benefit to little children, whose health often requires a daily sea bath, and who cannot face the open sea without such tears and struggles, and such a fright, that it is an open question whether it does them more harm than good. In addition to this there is a hydropathic department, in which salt water is employed, under the doctor's orders, in baths of different temperatures, in the form of shower baths, of douches, combined hot and cold baths, of local baths, and local injections. Dr. Macario, the well known Physician of Nice, and author of numerous medical works, resides at the establishments during the summer, and takes charge of the baths. He was good enough to show me the different baths, and explain their actions to me.

But the unique feature of the Croisic baths is the employment of mother liquor, obtained from the neighbouring salt gardens. The mother liquor is added to the ordinary sea baths in different proportions, from one to 100 litres, according to circumstances. In this way a sea bath is obtained of any required degree of strength. The mother liquor, or *eaux mères* as it is called in France, is the concentrated solution of sea salts, left in the salt pans after the extraction of bay salt. It contains a variety of salts, besides empyreumatic matter, resulting from the oxidisation

of the dead organisms of the sea. An analysis, by M. Jules Lefort, of a specimen litre at 25° B., gave the following solid contents:—

	Grammes.
Sodium chloride	297·498
Magnesium do.	33·241
Lithium do.	0·058
Potassium do.	0·322
Ammonium chloride	indications
Sodium bromide	4·819
Sodium carbonate	0·124
Calcium sulphate	1·884
Magnesium sulphate	16·832
Organic matters and silica	indications
	354·778 Grammes.

Mother liquors of densities from 32° to 35° B. are often used at the baths, and they are still more powerful, containing the same salts in yet larger quantities.

It is contended that, by the use of this mother liquor, the sea bath is completely controlled by science, which makes it stronger or weaker, as the case may need; and that without having recourse to the prolonged baths required at certain salt springs, where increased effects are obtained by longer baths, the same results are rapidly attained at Croisic, by the addition of mother liquor. It appears that in their physiological effects, these baths are somewhat irritating at first; and that it is necessary to proceed by degrees, and with caution, to larger doses. After a time a pustular eruption appears, which is considered as a favourable crisis, and this necessitates the interruption of the baths for a few days.

These baths are found of the greatest benefit to scrofulous people, especially to children suffering from the early forms of that disease, to convalescents from exhausting diseases, or after operations: for uterine affections, chlorosis, chronic

syphilis, and eczema. All classes of parasitic skin diseases are markedly benefited : various unclassed debilities, chronic ulcers, chronic mucous discharges, chronic diarrhœa, and rheumatic complaints, especially muscular; stiff joints, etc.

What Preissnitz, its inventor, has done with hydropathy, pure and simple; what the German Doctors have done with their noted salt springs; what the best conducted sea baths have done under medical advice; all this and perhaps more is done at Croisic, by their combined actions. Open air sea baths, enclosed sea baths, local baths, douches, and injections of all kinds; baths of every temperature and baths of every degree of saline concentration, are there employed together.

Another feature of the Croisic salt cure, is the use of hot sea-sand baths, which are reported to be extraordinarily efficacious in the treatment of certain chronic rheumatic joint affections. Patients can bear a higher temperature of sand than of water; and in the long run it is found that the congestion of the surface induced by the hot sand baths overcomes the chronic inflammation in the interior of the joint. The same has been noticed in disease of the periostium, and of the bones. The efficacy of this mode of treatment by salt is thoroughly recognized by the Medical Profession in France, and patients are sent to Croisic from all parts of France. They assemble there to the number of about two hundred, in the month of August, annually, and enjoy the mental advantages of agreeable society, music, theatricals, &c., in addition to purely physical treatment.

I have entered into details as regards Croisic, not by way of advertising it—though it is welcome to that advantage—but with a view to open the eyes of those who possess equal facilities in Britain, and "Greater Britain," to what may be done at a sea side place possessing salt gardens, as,

for example, Ennore, near Madras: what might have been done at the now extinct Hayling Island salt pans.

It is owing to the stimulant action of salt upon the skin that bathers are less liable to cramp in sea water than in fresh water. Salt spray stimulates the digestive and other mucous membranes, having a marked influence on the appetite and the digestion, as is noticed by all visitors to the sea side. It favours nutrition, and improves the tone of the muscles. It has a special influence on the lymphatic glandular system, resembling in this respect the iodides and bromides, with which it is, indeed, associated in nature. Its tendency is to resolve tumours, by stimulating the system to absorb them. Chronic sores, and discharges of all sorts, are manifestly benefited by it.

An analysis of the Atlantic, near Arcachon, Bordeaux, by Faurè, shows common salt, 27·956 parts per mille; magnesium chloride, 3·785 parts; magnesium sulphate, 5·575 parts; sodium sulphate, 0·483; calcium chloride, 0·325, and carbonates, 0·315 parts per mille.

The following is an imperfect list of the better known European "sources" which are frequented for the treatment of disease, and which owe their value to common salt. The percentage of salt in each spring is marked. In France, Balaruc, ·70 p. ct.; Bourbon, ·13 p. ct.; Bourbon, (larchamboult,) ·22 p. ct.; Bourbonne, ·58 p. ct.; Motte (la), ·38 p. ct.; Salies de Bearn, 229 grs. per litre; Salins (Jura), 2·27 p. ct.; Salins (Savoie), 11·31 p. litre; Tercis, ·21 p. ct.; Uriage, ·60 p. ct. In Italy, Abano, ·38 p. ct.; Acqui, ·17 p. ct.; Battaglia, 17 p. ct.; Ischia, 1·39 p. ct.; Monfalcone, 7 p. ct.; Montecatini, 1·85 p. ct. In Spain, Archena, ·25 p. ct.; Arnedillo ·51 p. ct.; Cestona, ·50 p. ct.; Cluclan, ·441 p. ct. In Switzerland, Baden (Argovie) ·16 p. ct.; Wildegg, 1·04 p. ct. In Germany, Creuznach, .95 p. ct.; Heilbrunn (Bavaria), ·49 p. ct.; Hombourg, 1·3 p. ct.; Kissingen, (Bavaria) ·58 p. ct.; Krœsen, (Prussia) 4·10 p. ct.; Kronthal, (Hesse) ·35 p. ct.; Mergentheim, (Wurtemberg) 1·33 p. ct.; Nauheim, (Hesse Darm) 1·42 p. ct.; Salzungen, (Saxe Men) 25·65 p. ct.; Soden (Hesse) 1·49 p. ct.; Niederbrom, (Alsace) ·30 p. ct. In Austria, Ischl, 2·90

p. ct. And in England, Cheltenham ·68 p. ct.; Leamington, ·342 p. ct.; Harrogate ·118 p. ct. The Saratago springs, in New York State, are also largely impregnated with common salt. They are peculiar in being perfectly free from sulphates; and in containing valuable lithium, strontium, and barium salts, not found, because precipitated by the sulphates, in other saline springs.

The hot springs of Las Vegas in New Mexico, contain about 27 per mille sodium chloride, 14 sodium sulphate, besides calcium and magnesium carbonates.

Salt is a useful aid to medical electricity. The human skin is a bad conductor of electricity, but its resistance is greatly diminished by the application of salt and water; salt solutions are therefore used to enable the electric current to act with greater freedom on subcutaneous tissues.

The potability of salt water is often a question of first rate importance. It may be rendered potable by filtration, by freezing, and by distillation. Filtration is a tedious and unsatisfactory process, demanding the use of a large number of filters. Mr. Godfrey, 1739, and Berzelius, found that when salt water was passed through a filter, the first part that came through was fresh. Bacon, who investigated this question, states that "if salt water be filtered through ten vessels of earth, it will not lose its saltness; but drained through 20 it becomes fresh and potable."

When sea water crystallizes, under the influence of cold, it parts with its salts and freezes into a nearly pure water ice. Sea water freezes just below the temperature of 28° F., a temperature easily commanded by a good ice machine. Ships, therefore, provided with ice machines, such as Carré's amonia machine, for example, need not fear shortness of water supply. Although potable, and fit for cooking, this ice water still retains a little sodium chloride —about 0·5 grammes per litre. The amount is according to Parkes. It does not form a palatable drinking water, however, owing to its saltish taste.

Distillation is the ordinary method employed for the conversion of salt water into fresh. The water is separated from the salts as steam, by boiling, and the steam being condensed, yields potable water. In 1813 the French Government instituted a series of experiments at Brest, Toulon, and Rochefort, on the use of distilled sea water for cooking, potation, and bread making. In the result, distilled sea water was found to be a healthy substitute for ordinary fresh water; and its use was sanctioned in the Navy, and on foreign stations, wherever fresh water was not procurable. During the Abyssinian war, this method of obtaining drinking water was carried out, on a very great scale, at Zoula. In Annesly Bay, several steamers were at work, day and night, for some months, condensing sea water for the sailors and troops. The author, then a Surgeon with the forces, lived on condensed sea steam for some days, and can testify to its being a healthy potation, free from the flavour of salt. It has been often found to have a bad smell, being penetrated with the odour of decomposition, owing to distillation of various organic matters contained in the sea. This may be prevented by frequently cleaning out the boiler; and by placing lumps of charcoal in it to absorb gases. These are practices which should not be neglected. It should be noticed that the presence of salt in potable waters, in chalk or limestone districts, and in other situations away from the sea, in which the mineral, rock salt, does not occur, is generally a warning of sewer pollution. Salt is contained in human excretions, and in those of animals. Roughly, there should not be more than one grain of salt to the gallon of drinking water; which gives a mere cloudines with lunar caustic. The water to be tested should first be rendered acid with a few drops of nitric acid.

The question has more than once been raised, can life be supported in extreme cases by sea water alone, without any preparation or alteration whatever? There is not sufficient evidence to support a definite conclusion on this point, certainly not enough to justify the use of salt water, but there is quite enough to excite interest and to promote a desire for further knowledge. We are dependant unfortunately for our facts, in a great measure, on the stories of shipwrecked mariners, and the chance observations of distant travellers.

The *Journal de la Societe de Medicine de Caen et de Calvados* publishes the following account of salt water drinkers, taken from an account of a voyage to the Oceanic Islands, by M. Jouan, a ship's captain, and sent by him to a medical man at Caen. These remarkable people are met with on the madreporic *atolls* of the Pacific, such as the Paumoton Islands, where there are neither brooks nor springs, and where the wells, which have been dug, yield only brackish water. The vegetation is limited to a few cocoanut-trees, the milk of which, with sea water, constitutes the only drink of the natives. The fact is affirmed by the majority of navigators who have visited those distant shores. Cook and Laperouse both mention it, and more recently, Dupetit-Thouars has described the inhabitants of Easter Island as true amphibia, drinking sea water without feeling any inconvenience from it. M. Jouan concludes his observations on the drinking of sea water by a fact, which he asserts to have seen at the beginning of his sea-faring career, in 1838, while going to Mexico. At that time, he writes, steam navigation had not yet freed ships from the influences of calms and head winds. There was no distilling apparatus, so that on long voyages, it was necessary to be careful with the water; and in his ship, with the number on

board nearly doubled by some troops they had to convey, and the prospect of not finding any water on the way, since they were only going to blockade the coast without communicating with the shore, they were specially parsimonious in its use. Some sailors consequently began to drink sea water, but were soon obliged to leave it off. One man only persevered until the ship arrived at Mexico, where it was revictualled with fresh water, brought at great expense from Havannah. This man never complained of the sea water; the only difference remarked in him was that he became more and more yellow.—*British Medical Journal.*

According to the *Toronto Herald*, there is a wonderful old gentleman in New York, named Mr. Lorenzo A. Pickles, who, though seventy years old, looks not more than forty. Salt is his *elixir vitæ*. He lives upon salt, salted fish, and salt pork, his drink being salted tea.

The Indian papers reported, lately, the case of two natives driven out to sea on a raft, who subsisted for 15 days on salt water; one died from exhaustion, after being picked up.—*Madras Mail, 24th April,* 1882.

On the other hand, the authors of romance have settled that salt water is a fatal poison. Tales of *Castaways* abound with cases of water starvation, in which men who have assuaged their thirst with salt water, have speedily died, in an outburst of delirium or suicidal mania. If such cases be authentic, the question arises, what value is to be placed on the testimony of survivors, enfeebled in mind and body? The main facts, delirium and death, can be accounted for apart from salt water drinking. Starving men, in the last stage of exhaustion, exposed to the chill night air, and broiling sun, by turns, haunted by the imminent danger of death from starvation, or worse, may become delirious, and die by suicide or exhaustion. There is no apparent reason why

sea water should act as a rapid poison. A pound of it contains 188 grains of common salt, 25 grains magnesium chloride, and 20 grains magnesium sulphate. We may leave out of the question the inert lime salts, and some others which are fractional in amount. Now, these salts, in these amounts, are not, in a theoretical sense, poisonous. Practically, also, we know that they are taken with impunity by bathers, such as those who bathe frequently in the day, and by habitual salt water drinkers. Many peasants, on the Irish Coast, not only drink a mug of sea water in the morning, but also cook their potatoes in salt water, and get the full benefit of these salts, both ways, with robust health. However, a pound of sea water acts as a laxative, and is employed for that purpose; and the continued use of these salts, without a corresponding supply of fresh water, has never yet been tried experimentally. Moreover, the action of magnesium chloride on the system is not well known. It is probably more energetic than common salt. We may consider the question as it regards thirst.

There is no doubt that salt, *per se,* or in the form of red-herring, or salt meat of any kind, produces thirst. And thirst, under these circumstances, must be taken as the expression of a desire on the part of the body to get rid of excess of salt, by dissolving and excreting it. Here we have an excess of salt, consumed in the *dry state,* demanding an excess of fluid for its removal. In starvation there is thirst of another kind; the body, which is chiefly composed of water, is being deprived of that water. It goes into the circulation to prolong life, and is lost by excretion and respiration. This is a state of the body, apparently less favorable to the reception of salt water, than is its condition in robust health. Yet, in a parallel state, in the second stage of Asiatic cholera, when the body has been reduced to the condition of a

skeleton, by loss of water in choleraic discharges, and the sensation of thirst is overpowering, saline injections into the veins, have been known to alleviate thirst. (Carpenter's Physiology, (Power) 8th edition, p. 107.) Does the potation of sea water cause thirst in healthy persons? Bathers will probably answer 'yes'. The fact is, even a few drops of salt water leave a saltish flavour in the mouth, due in great part to the action of magnesium chloride, which is most disagreeable. It is probably the gustatory nerve which is affected. A larger potation of salt water does not increase the salt thirst in the least, as far as my experience goes, bathing five hours after drinking.

Does the sea contain sufficient water, in proportion to its salts, to leave a balance of water for the general purposes of the system, after having carried off the salt it brings? The sea contains from 34 to 40 parts of salt in a thousand. The blood only contains 7 parts of salt in a thousand, in its normal state; and the urine only about 10 parts per mille. But the condition of the blood in starvation, *qua* salt, has not been studied. Although the kidneys are capable of excreting urine highly charged with salts, that is not the direction in which relief is to be expected, in this case, for the salt would have first to pass through the blood. It is true that strong brines have been used as intravenous injections, without producing poisonous symptoms: but magnesium chloride has not been so used, and the presence of that salt complicates the question. Unless the salts of the brine are eliminated, at once, by the bowel, it seems probable that sea water does more harm than good. They cannot be eliminated by the bowel unless the relations of endosmose and exosmose are quite altered. Under ordinary circumstances salt acts as a watery purge, by withdrawing water from the blood. Only under extraordinary circum-

stances could it be deprived of its water by thickened blood, and excreted dry. There is something, however, to be said for vital selection, or the power which living matter has of selecting what it requires, and rejecting what is hurtful to it; and as the blood is the life, it may not always act, as in a laboratory experiment on exosmose.

In many wasting diseases, saline solutions are relished, as the quantity of salt in the blood is below the normal standard. Its condition in starvation is however problematical.

Apart from these theoretical considerations, which throw an uncertain light upon the question, we have the fact that the seal, the porpoise, the whale, and other marine animals, representing carnivorous and herbiverous habits, whose flesh and blood is hardly distinguishable from that of terrestrial animals, live exclusively on sea water as a potation. The Reindeer is said to drink salt water at certain seasons. And a large number of birds, some of which can be domesticated, exist on salt water. Sea water, moreover, is something more than a solution of salts. It contains millions of microscopic organisms, which, though small in size, form in the aggregate, a body of nitrogenous food, that must be very valuable to persons perishing from starvation. The eccentric individuals who fast for periods of 30 days, and upwards, on a water diet, must owe their safety to this nitrogenous element in the water; if to nothing else. But fresh water is not so rich in nitrogenous bodies as sea water, which swarms with animalculæ.

What is required to settle this question is a practical experiment, voluntarily undertaken, under proper conditions. I made the attempt once to live on salt water, in the Indian Ocean, when the thermometer stood at 85° F., and succeeded for 21 hours; that is, from 9 o'clock on one night, until 6

o'clock on the following. I took a pint of the particularly strong sea water of the Indian Ocean, in small quantities at a time, during the day. At six in the evening, the mucus secretion of my mouth was decidedly thick, and I was very thirsty, I broke down at 6 o'clock not because I was overcome by thirst, but because it was dinner time, there were iced wines on the table, and the *menu* included iced cream. An experiment of this kind to be of much use, should be prolonged for a very disagreeable space of time.

Without pronouncing on the question of the potability of salt water, one way or the other, it may be pointed out that the sea differs in amount of salt very considerably; and that in the polar regions, extending to 20 degrees from the poles, also within a few miles of land, where large rivers join the sea, it is comparatively fresh. My brother, Dr. John Ratton, writes, that when on the Altantic, 140 miles from land, off the mouth of the river Amazon, the water was only brackish to the taste. Again, rain water being specifically lighter, lodges, especially in calm weather, on the surface of the sea, and often renders it unquestionably potable.

We are usually recommended to immerse the body in the sea, if shipwrecked and dying for want of water: but not to drink it. But by doing so we call into play, through the skin, the same function of endosmose and exosmose, which would take place more readily through the mucous membrane, if we were to drink it. If the skin has the power to absorb the water and reject the salts from the sea; so probably has the mucous membrane in a still greater degree. And it is likely that the sensation of thirst, partly caused by the action of salt on the gustatory nerve, might be avoided by taking it as an enema.

CHAPTER VII.

ARTS AND MANUFACTURES.

It is when we come to consider salt in the aspect of a manufacturing element that we become aware for the first time of its real commercial value. In England it has been, and still is, a source of great wealth. Other countries are much indebted to it, in this way; but not to the same extent: Lancashire and Cheshire with abundant salt, cheap coal, and Liverpool as a point of export, have unrivalled advantages, which have developed their salt manufactures to a degree unknown elsewhere. Of salt manufacture itself we shall speak hereafter; for the present we are concerned with the important group of industries which are the offsprings of cheap salt, and which are generally known as chemical works. The most important of these is the manufacture of soda, or alkali, as it is commonly called. In the year 1876, 538,600 tons of salt, 1,890,000 tons of coal, and 588,000 tons of limestone, were employed in this manufacture. The capital employed in the trade amounted to £7,000,000. The number of hands employed amounted to 22,000, and the value of soda exported to £2,209,284.

Alkali Manufacture.—This name is given to the process of extraction of sodium from common salt, invented by Leblanc. It originated, as the name implies, in France.

When France was under the ban of the European coalition, and could no longer procure soda from without, the genius of Nicholas Leblanc supplied her with the means

of producing it from common salt. This process of soda manufacture, still known as the *Leblanc* process, is one of the greatest discoveries of the present century. It has enriched thousands; though not, unfortunately, Leblanc himself, who died in poverty in 1806. Owing to the high duty on salt in England, the Leblanc process could not be adopted before 1823. In that year M. Muspratt started it at Liverpool. In 1825 the duty on salt was abolished altogether; and from that time it has rapidly increased in importance. It is now the most important of all the chemical manufactories of the day in England. It comprises the manufacture of sulphuric acid, which, however, is a separate business: the decomposition of common salt by the action of sulphuric acid, with the resulting formation of sodium sulphate and hydrochloric acid; the utilizing of hydrochloric acid for making bleaching powder; the formation of sodium carbonate and calcium sulphate, by the decomposition of sodium sulphate and calcium carbonate, and the separation of the former by lixiviation.

The decomposition of salt by means of sulphuric acid is performed in the salt cake furnace, and is called the *salt cake* process. It is the first step. It is well described in Fowne's Chemistry. The furnace consists of a large covered iron pan, placed in the centre, and heated by a fire underneath; and two roasters, or reverberatory furnaces, placed one at each end, on the hearths of which the salt is completely decomposed. A charge of half a ton of salt is first placed in the iron pan, and then the requisite quantity of sulphuric acid is allowed to flow in upon it. Hydrochloric acid is evolved, and escapes through a flue, with the products of combustion, into towers or scrubbers, filled with coke and bricks, moistened with a stream of water. The acid vapours are there condensed, and the smoke and

heated air pass up the chimney. After the mixture of salt and acid has been heated in the iron pan, it becomes converted into a solid mass of acid sodium sulphate and undecomposed sodium chloride. :—

$$2NaCl + H_2SO_4 = NaCl + NaHSO_4 + HCl.$$

It is then raked on to the hearths of the furnaces at each side of the decomposing pan, where the flame and heated air of the fire complete the decomposition into neutral sodium sulphate and sulphuric acid :—

$$NaCl + NaHSO_4 = Na_2SO_4 + HCl.$$

The next process is called the *Soda-ash process.* It has been much improved of late by the use of revolving furnaces. The sodium sulphate produced in the salt cake process is powdered, and mixed with an equal weight of chalk or limestone and half as much coal, 40 to 60 per cent., according to quality, both ground or crushed. This mixture is placed in the furnace, about 2 cwt. at a time, and slowly revolved until the sulphate has melted and decomposed into black-ash or ball-soda. The furnace is then stopped, and a quantity of caustic lime in small pieces is added; also cinders to keep the charge porous, if it seems to require them. The furnace is then put in motion again; the lime rapidly mixed through the charge, and the charge quickly withdrawn. The caustic lime acts by breaking up the black-ash.

It is claimed for this new method of manufacture that the out-put is increased 50 to 70 per cent.; a large saving in limestone and coal is effected; the quantity of waste is reduced; there is less insoluble black-ash formed; the lixiviation is greatly assisted; and a larger yield of alkali is obtained from a given quantity of sodium sulphate.

The crude product, called *black-ash*, or *ball-soda*, is broken up into little pieces, when cold, and lixiviated with cold or tepid water. The solution is evaporated to dryness, and the

salt calcined with a little sawdust in a suitable furnace. The product is the *soda-ash*, or *British alkali* of commerce, which, when of good quality, contains from 48 to 52 per cent. of anhydrous soda, Na_2O, partly in the state of carbonate, and partly as hydrate; the remainder being chiefly sodium sulphate and common salt, with occasional traces of sulphite or thiosulphate, and also cyanide of sodium. By dissolving soda-ash in hot water, filtering the solution, and then allowing it to cool slowly, the carbonate is deposited in large transparent crystals.

The reaction which takes place in the calcination of the sulphate with chalk and coal-dust, seems to consist, first, in the conversion of the sodium sulphate into sulphide by the aid of the combustible matter, and, secondly, in the interchange of elements between that substance and the calcium carbonate:

$$Na_2S + CaCO_3 = CaS + Na_2CO_3."$$

Ammonia Process.—This process depends upon the reaction of carbonate of ammonia and common salt upon each other, in aqueous solutions. It was tried and abandoned in 1838; but is now again attracting much attention. A lecture experiment, illustrating this method of producing the soda, is described by Mr. E. J. Hallock. It consists essentially of a cylinder filled with a saturated solution of common salt, and separated into divisions by wire gauze. Carbonic acid gas is introduced at the bottom of the cylinder, and ammonia at the top. The resulting ammonia bicarbonate is decomposed by the sodium chloride in the solution, into ammonium chloride, and sodium carbonate, which latter is deposited upon wire nets. In the practical application of this process, ammonia bicarbonate precipitates soda bicarbonate from a strong solution of common salt, leaving ammonium chloride in solution. The ammonia is afterwards

expelled from the solution by quicklime, with the formation of chloride of lime. The ammonia is then available for the next process. Then carbonic acid is driven off from the sodium bicarbonate, and reconverts the ammonia into bicarbonate of ammonia; and the operation begins again as before.

The advantages claimed for the ammonia process are that *only* the soda is precipitated from the salt solution. That the soda is of a high quality. That the conversion of salt into soda is direct, and free from sulphur compounds. The apparatus and utensils are simple and comparatively cheap. There is a great saving of labour and of fuel. No noxious gases are given off. And there are no waste products. It requires however for its working, cheap salt, cheap ammonia, and cheap limestone. There are only two or three works of the kind in England, and they are close to the Cheshire Salt Mines. In Belgium, an extensive work of this kind is carried on in a limestone quarry. It is hardly likely to supersede the Leblanc process in England, unless salt and ammonia become much cheaper than they are. At Aalborg in Denmark, there is an *Ammoniac Soda Manufactory*, which from advertisements in the Chemical News, Dec. 7, 1877, appears to have turned out 200 cwts. of soda daily, at a consumption of 400 cwts. rock salt, 210 cwts. coal, 45 cwts. coke, 10 cwts. ammonium sulphate, 2 cwts. sulphuric acid, and 160 cwts. chalk. This work appears from the consumption of coal and chalk to have been quite as much Leblanc as ammoniac. It employed 45 hands. This will give some idea of its nature and expense.

In May 1881, I visited the ammonia alkali works of Messrs. Brunnur and Mond, at Wheelock in Cheshire. They employ a number of large iron cylinders, in sections, for the mining process; and the carbonic acid, ammonia, and salt solutions are pumped in by steam. There is a big machine

room, in which a powerful engine is constantly at work. The carbonic acid is derived from a limestone kiln on the premises. The brine comes from the Wheelock spring. It is saturated with sodium chloride and free from magnesium salts. The process seemed to be in a great measure automatic, except in the extraction room, where workmen were employed in removing the alkali. The salt ash, or refuse, dissolved in water at 80° F., and allowed to stand and crystallize, yields beautiful crystals. One chamber was devoted to this process. There was a strong smell of ammonia about the works which indicates wastage. There was also a considerable pile of refuse. The manager, who had considerable experience of ordinary alkali works, claimed a great superiority for the ammonia process. I have no doubt that his own conviction about it is perfectly genuine, and consider it an important testimony in favor of this process. To make use of the calcium chloride, which is so much waste, as a rule, in chemical manufactories, a plan of treating it has been invented, which may prove profitable. One part of the waste calcium chloride, dried, is mixed with one and a half parts of fine sand, and the mixture is heated in a retort, through which at the same time a continuous current of steam is passed. The result of the process is the formation of hydrochloric acid and caustic lime; the steam combines with the chlorine to form the acid, which is gathered in the flues, in a way that will be described, and the lime remains with the sand.

Magnesium Method.—M. Bohlig has described another method of manufacturing *potash and soda* direct from their chlorides. Magnesium oxalate is digested with one equivalent of sodium chloride, or potassium chloride, and one of hydrochloric acid. The following reaction takes place $C_2 O_4 Mg + HCl + Na\,Cl = C_2 O_4 HNa + MgCl_2$. Mag-

nesium chloride remains in solution, whilst acid sodium oxalate crystallizes out. This is then washed and introduced into an autoclave, with a corresponding quantity of magnesium carbonate and water; carbonic acid is first disengaged. When the acid has been expelled, the autoclave is shut, and the mass is worked up with an agitator. The pressure rises to two atmospheres and falls again to nothing. The products of this reaction are a strong solution of sodium bicarbonate and magnesium oxalate, compact and crystalline. The solution of bicarbonate is boiled with magnesia, obtained by the decomposition of magnesium chloride by heat, when carbonate of magnesia is precipitated, and neutral carbonate of soda remains in solution.

Hydrochloric Acid, formerly known as muriatic acid, and "spirit of salt," is now largely obtained from common salt, as a bye-product in the manufacture of alkali by the Leblanc process. As it is driven off from the salt by the action of sulphuric acid, in the first stage of Leblanc's process, it is passed through flues, filled with porous cinders, wetted by a stream of water, and thereby condensed. Hydrochloric acid is also separately manufactured from salt and sulphuric acid, in a special apparatus. The acid gas evolved is passed into water, which, at 40° F., is capable of absorbing 480 times its bulk of hydrochloric acid. In doing so, it increases in volume one-third, and acquires a sp. gr. of 1·21. This is the acid of commerce. It is largely used in the manufacture of chlorine, sal ammoniac, antimony chloride, glue, phosphorus, the preparation of carbonic acid for mineral waters, beet-root sugar works, laboratory work, medicine, hydro-mettallurgy and for dissolving metals. The once celebrated *aqua fortis* consists of a mixture of hydrochloric with nitric acid.

The purer form of hydrochloric acid is prepared by passing the acid gas through glass or stoneware vessels, plunged

in a cooling tank. This acid is used in the production of chlorine, bleaching powder, in the manufacture of chlorides, in the preparation of glaze and gelatine, and in metallurgy. It may be also made by the mutual action of steam and common salt at high temperatures; or by the conjoint action of sulphur dioxide, air, and steam upon common salt.

Formerly the fumes of hydrochloric acid which escaped into the air from alkali factories injured vegetation to such an extent that two Acts of Parliament had to be passed for the suppressure of the nuisance. In a very short space of time trees and plants were blackened and destroyed. Now, by the recent inventions noticed, a great deal has been done to mitigate this nuisance.

Bleaching Powder.—The celebrated bleaching powder, which is used in enormous quantities in the bleach works of Lancashire, Scotland, and the north of Ireland, is manufactured with chlorine derived from common salt. About half a ton of common salt, mixed with 10 to 14 cwt. of black oxide of manganese, are introduced into a large leaden vessel, the lower part of which is cased in a hollow iron jacket, supplied with steam for generating heat. From 12 to 14 cwt. of sulphuric acid are then introduced through a twisted funnel, in successive portions, and the contents stirred up by an agitator, the handle of which passes through the top. As the chlorine gas forms, it escapes through a leaden pipe, which conveys it to the top of a separate chamber, the *lime chamber*, which is built of stone, cemented with pitch, resin, and gypsum. Here the gas, being heavier than air, filters down through the lime, which is contained in the form of powder, in trays, placed one over another, one inch apart. A window at each side enables the workmen to judge of the progress of the work by the colour of the gas, which is greenish yellow. After two days the door is

opened, and the lime raked in the trays to expose fresh surfaces to the gas; the gas is then re-admitted for two days more. The sulphate of soda and sulphate of magnesia, remaining in the retort, are then extracted through a tube at the bottom of the leaden chamber, and the process is repeated.

The chlorine contained in the bleaching powder, and extracted from the salt, is the active element in the bleaching process. Chloride of lime is very largely used now in sanitation, by municipalities and other public bodies, as well as by hospitals. It is the white powder so commonly seen in latrines of all kinds. Latterly, calcium chloride is made by the direct action of hydrochloric acid, produced as a bye-product of alkali works.

Bleaching powder owes its efficacy to chlorine. A solution of it is a powerful deoderiser, disinfectant, and bleach. It is a hypochloride of lime, $Ca\,Cl_2\,O$. It decomposes rapidly, especially if HCl be added. $Ca\,Cl_2\,O + 2\,HCl = Ca\,Cl_2 + H_2\,O + Cl_2$. This Cl_2 is not given off. It unites with the water $H_2\,O + Cl_2 = 2\,H\,Cl + O$, which is perhaps the real bleaching element. (Professor Church, M.A., F.C.S., "Acids." Bevan's British Manufactures.) About 100,000 tons of it were made in England, in 1874, by the Welden process alone. It is used in bleaching, calico printing, and sanitation. Esparto grass and other fibrous materials, used now in paper-making, require much more of it than did the rag pulp formerly used.

Chlorine.—The manufacture of chlorine from salt, for special purposes, is often conducted in the way already described under the heading of "bleaching powder." The making of bleaching powder involves two processes; first, the evolution of chlorine; and second, its reaction with lime. The best proportions for producing chlorine are, commercial oil of vitriol and water, each 7 parts, salt, 4 parts, and peroxide of

manganese, 3 parts. It may be mentioned that hydrochloric acid is also utilized for this purpose. The strong acid, poured on half its weight of black oxide of manganese, finely powdered, evolves chlorine copiously, especially with the aid of heat.

Soap.—There are two kinds of soap, soda soap, and potash soap. Soda soap only need be noticed here. This manufacture is dependant upon common salt in a two-fold way: first, indirectly, as the source of the alkali which forms the soap: and, secondly, directly, in the method of separation to be described. The introduction of the Leblanc's process gave a wonderful impetus to the soap trade. Ten years after its introduction, it was found that Liverpool alone exported more soap annually, than did all the sea ports of Great Britain, together, previously. It is necessary to know that a fat, or oil, consists of the combination of a fatty acid, stearic, oleaic margaric, etc., as the case may be, with glycerine. A soap is formed by an alkali combining with the fatty acid, and driving off the glycerine, which is set free. In England, tallow and soda are commonly used for making hard soaps, in the proportion of 85 to 90 parts of the former, with 15 to 10 of the latter. Tallow is a stearate of glycerine. When it is boiled with a solution of soda, stearate of soda, or soluble soap, forms, and is held in suspension by the water, together with the liberated glycerine. These are then separated by a solution of common salt. The excess of alkali and the glycerine, combine with salt water, and remain in solution; whereas the soap, being insoluble in salt water, floats to the surface, and is removed. The soda used in making soap should be caustic. It is rendered caustic by being mixed with recently slaked lime, and filtered. The lime removes its carbonic acid. In practice also the common salt solution is *mixed* with the *lye*, or soda solution, as otherwise the lye and tallow form a uniform

emulsion which burns the bottom of the boiler. The salt solution, which sinks to the bottom, prevents injury to the boiler. After the soap has formed, it is allowed to stand for some time, in order that the salt solution with which it is impregnated may be got rid of by exudation. In time, it all drains away.

Marine Soap.—Cocoanut oil and soda form a soap which differs from others in being soluble in salt water, even in very strong brine. It cannot, therefore, be separated from the lye and glycerine, unless the oil is largely mixed with other fats. Cocoanut-oil soap dissolves readily and forms a lather in sea brine; it is hence called marine soap. It takes up a large quantity of water, 50 to 70 per cent., in solidifying.

Ammonia Process.—There is another method of making soap direct from common salt, with the aid of ammonia. It is described by T. N. Whitelaw, in Chemical News, vol. 32, p. 152. When any fatty or resinous body, used in soap making, is heated with excess of common salt, ammonia, and water, soda soap forms and separates, while the solution retains the excess of ammonia and common salt, together with ammonium chloride. One hundred parts of fatty matter require 20 to 30 parts of sodium chloride, 15 to 20 parts of ammonia, and 200 to 300 parts of water. With free fatty acids, or resins, soap forms at once, on heating in a closed vessel. With neutral fats, however, it is better to heat the ammonia solution and fat, in a closed vessel, up to 150° C: this gives rise to ammonia soap and glycerine. The ammonia soap can then be decomposed with common salt as just described. Allowing for the loss, of ammonia, which is 5 per cent., there is a saving of alkali manufacture, of labor and of fuel, which would make this direct soap cheaper than that made in the ordinary way.

Dyeing.—Salt or soda is very largely used in organic chemistry in the synthetical preparation of a number of new compounds, such as indigo and madder. This is especially the case in Germany, where great attention is given to the production of artificial dyes and other valuable organic salts. It is also largely used in the ordinary dyeing processes of Lancashire. A Manchester Chemist, engaged in this business, informed me in 1881, that about 20 tons of salt a month, were then used in the dyeing works of Manchester alone, chiefly for oxidising purposes for madder colours. As a good deal of money is made out of special chemical knowledge in the dyeing industry, some reserve is maintained regarding it, and I am unable to supply full details of the process.

Glass.—Salt is used in the manufacture of inferior glass, such as that used for wine bottles. M. Pillat gives the following composition of the mass in France. Sand, 100 parts; soapers waste, 80; gas lime, 80; common clay, 5; and rock salt, 3 parts. Another formula for pale green glass, is pale sand, 51 parts; lixiviated wood ashes, 33 parts; dried pearl ashes, 8 parts; common salt, 7½ parts; white arsenic, ½ a part. Glass is a mixture of the silicates of soda, lime, potash, lead, etc., with an excess of silicic acid. Silica, in the form of sand, is heated with salt or soda and lead oxide, or slaked lime, to form common bottle glass. The heating is carried on in furnaces of firebrick, until the mass is quite melted and fused together and bubbles cease to form. The mass is then allowed to cool until it acquires the requisite tenacity for glass blowing. This is the commonest form of glass. There are a variety of others in which there is no soda. There are, also, stained glasses, coloured by the addition of various salts.

Pottery Glaze.—The glazing of stone-ware depends upon

a peculiar mode of decomposition of common salt. Sodium chloride is not decomposed by heat alone, and if heated with dry silicic acid, no decomposition takes place. But in the presence of silicia and some substance capable of parting with oxygen to the sodium, and of abstracting its chlorine at the same time, as steam or oxide of iron, the salt will decompose at a high temperature, sodium silicate and perchloride of iron, or sodium silicate and hydrochloric acid, being formed. The unglazed pottery, after having been dipped in sand and water, is slowly raised to an intense heat in a kiln, then a certain amount of moist salt is introduced. The salt is converted into vapour, which is decomposed by the silica and oxide of iron in the clay, aided by the steam coming from the fuel in the furnace. Iron perchloride and hydrochloric acid pass off in vapour with the excess of salt, whilst silicate of soda forms upon the pottery and glazes it, rendering it impermeable.

Assaying.—A common salt *test solution* is in ordinary use for assaying silver in the principal mints of the world. Three solutions are required: 1, A standard normal solution of sodium chloride; 2, A decimal solution of sodium chloride; 3, A decimal solution of silver. The salt used is, in the first place, treated with caustic baryta, in order to remove sulphuric acid and magnesium; a slight excess of carbonate of soda is then added; the solution warmed, and the precipitate allowed to subside. Next comes evaporation and separation of crystals on a filter, by filtration; then the crystals are washed slightly with distilled water, dried, and heated to a dull redness. 54·162 grs. of this pure salt, will exactly precipitate 100 grains of silver.

Roughly, the assay is made as follows. A standard solution of the salt, 1,000 grains of which will just precipitate 10 grs. of silver, is first prepared. Ten grains of the

alloy to be examined is then dissolved in two drachms of nitric acid of sp. gr. 1·25, with gentle heat, in a stoppered bottle. The standard solution is then placed in a burette, and the apparatus weighed. The salt solution is then dropped from the burette, slowly, into the silver solution; and the drops are continued as long as any cloudy white precipitate of silver chloride forms; the bottle being shaken up from time to time to maintain uniformity. The burette is now reweighed; and the number of grains of the standard solution used, indicate the weight of silver in the alloy. In practice, a standard solution and a decimal solution are employed. Salt is also largely employed in silver mines, in the refinement of the pure ore.

Galvanic Battery.—M. Niardet, read at the Academy of Sciences, Paris, Oct. 27, 1879, a paper on a new form of galvanic battery. The positive electrode is a zinc plate in a solution of sodium chloride; the negative, a carbon plate surrounded by fragments of carbon and chloride of lime in a porous vessel. All the combinations produced are soluble, and the battery remains an indefinite time at rest, without being used up. The electro-motive force, at first, is over 1·6 volts.

Silvering Metal.—A useful silvering liquid may be made with silver chloride, 3 parts, cream of tartar in fine powder, 20 parts, and common salt finely ground, 15 parts, mixed and rubbed to a thin paste with a little water. This should be spread with a soft brush over clean metal, and when dry, polished with precipitated chalk.

Ice Machines.—Strong solutions of salt are used in some ice machines to carry cold from the refrigerator to the water to be frozen. Karsten found that water containing 28 per cent. of salt resisted the crystallizing action of severe frost. Such water does not form ice at temperatures above

—17·77° C. It can be reduced therefore to—16·17° C. and circulated at that temperature, around fresh water tanks, causing the fresh water to freeze into solid blocks of ice. In principle this is what is done in *ice rinks ;* but the brine is a complex solution, containing, like the mother liquor of bay salt manufacture, magnesium chloride, and other highly deliquescent salts, which enhance the resistance of the brine to cold. Such brine will take into circulation over 25 degrees of frost, so called. Something can be also gained by making the common salt solutions stronger than 28 per cent., but it must be remembered that a 37·5 per cent. solution is liable to crystallize into the hydrate at—10° to—15° C. Salt is very largely used by German Brewers, in the form of frigorific mixtures, for keeping down the temperature of their famous beer vaults. The consumption of salt for this purpose, in Germany, ranks next in importance to that used in chemistry, and above soap manufacture.

Confectioners, and Italian ice vendors, use, in the aggregate, very large quantities of salt in freezing mixtures for the manufacture of sweet ices. Schleiden says that the daily consumption of salt in the best confectioner's shops in Berlin, in the summer, is from 1 to 1½ cwt.

Salt is also used by confectioners, mixed with sugar, for seasoning pastry and sweet meats. There is hardly a sweet dish, from a tart to a Christmas plum pudding, which does not contain salt.

Tanning.—Salted skins are more durable and smooth than dried skins, and are much preferred by tanners. To prepare one skin, 15 lbs. of salt are required. Some idea of the amount of salt used in this business may be gathered from the facts given by Schleiden, Das Saz., p. 170. In Brazil 3,600,000 head of cattle are killed annually, the flesh and skins of which are salted. A large number of horses are

also killed in South America for the tanner, and their skins salted. Uruguay alone, in 1866, killed 30,400 horses. A great deal of salt is used in India by tanners.

Bleaching Oils.—Linseed oil, nut oil, and other vegetable oils, used for making varnish, etc., are bleached by exposure in thin strata to the sun's rays, in wide flat vessels, filled with a solution of common salt, on which they float. The salt water absorbs mucilage, purifies the oil, and prevents it from subsequently turning rancid. It takes from two days to a week to bleach the oil, according to its quality, and the power of the sun.

Tobacco.—Common salt, it may be mentioned, is used by some tobacco manufacturers, instead of sugar, to increase the weight of the finished article. They spread the leaves out on a pavement, and water them with a salt solution of sp. gr. 1·107. The leaves are left in this state for three or four days, according to the temperature and kind of tobacco. The salt helps to preserve the tobacco; but its chief object is to attract moisture from the atmosphere, and increase its weight. Hence, inferior salt is preferred.

Forging.—Iron files, taken from the furnace, require a protecting medium to preserve them from oxidation; this is made with a combination of salt, yeast, and flour. Major Serpo Pinto, "How I crossed Africa," London, 1881, mentions that the Gonzellos miners tempered their iron with salt and ox grease: and he describes their knives and guns as being very good. In melting metals, salt is used to preserve the surface from oxidation, by defending it from the air.

Timber.—The dry rot in timber results from the ravages of a parasitic fungus, which, like other parasitic growths, is killed by salt. It is a noted fact that in the salt mines of Poland and Hungary, the galleries are supported by wooden pillars, which last for centuries in the salt atmos-

phere of the mines; whereas pillars of brick and stone crumble away in a short time by the decay of their mortar. It is also found that the wooden piles driven into the mud of salt flats and marshes last for remarkable periods. Such piles are often used for the foundation of brick and stone edifices. The practice of docking timber, by immersing it for sometime in sea water, after it has been seasoned, is generally admitted to promote its durability. There are experiments tending to prove that immersion in salt water will check dry rot, even after it has begun.

Special Forms of Salt.—In France, agricultural salt for cattle is largely manufactured from sea salt. In England, also, a special form of solid salt is made for farmers. In the Cheshire Mines, the hardest part of the rock-salt seam is reserved for making "block salt" for cattle.

Variously named sea salts are now largely manufactured in England for household use. They are widely advertised under the name of their patentees, and may be purchased at every grocer's shop.

Gold mining may now be added to the number of industries employing salt, since recent experiments at the Wynaad gold fields have shown the value of chlorine in extracting gold from pyrites.

Miscellaneous.—Salt is more or less needed in a number of other industries, as by farriers, color manufacturers, coopers; in woollen factories, catgut factories, cloth manufactories, amidon factories; by ship-builders, zinc founders, glove-makers, rope-makers, brass-founders, photographers, tanners, paper manufacturers. The white paper on which these lines are printed, owes its purity, indirectly, but very certainly, to salt. Salt water, as will be noticed later, is used in the formation of artificial stone.

Artificial Manure.—Salt is largely used in the manufac-

ture of chemical manures. It is contained also in natural manures, as guano. In the next chapter, on agriculture, will be found a good deal of information on this subject.

Museum Work.—A salt solution may be made use of for the purpose of preserving specimens in Museum work. Attention has been drawn to this subject by Professor De Candolle, who examined chemically the liquid in which a branch of a coffee plant had been preserved for about fifty-three years, and found it to be boiled sea water. He came to the conclusion that a boiled solution of salt might displace alcohol for Museum work. The carbonic acid and oxygen gases are removed by boiling, and microscopic septic organisms, are destroyed. I have tried in India the experiment of preserving a portion of the human body in a boiled saturated solution of salt, marking 25° Beaumé. This liquid requires to be raised to a high temperature 230° F. In boiling; its gases are driven off, and if any septic organisms remain in it, they are killed by the temperature. For the time that I was able to watch this experiment, the preserving liquid answered its purpose very well. At the end of two and a half years, the specimens were, as seen through the glass, in perfect order; and they are so at date of publishing. It is a cheap method of keeping specimens where salt is cheap. The idea is a very old one, since, according to Herodotus, the Egyptians preserved the bodies of their great ones in a strong brine for 70 days, before converting them into mummies.

Preservation of Steel.—A saturated solution of salt, boiled and corked, will also preserve steel instruments and other objects which it is necessary to defend from the oxidisation of the atmosphere. It is a favorite tale with the foremen, *cicerones* of the Cheshire salt works, that penknives, dropped

into the boiling pans, are taken out, after the lapse of some months, as bright as when they entered.

Curing and Preserviny.—Salt is extensively used in fish-curing, and in preserving meat, butter, cheese, etc. The poorer classes in most countries are dependent upon salt for a supply of animal food; so also all, but the "upper ten" of those who live at sea. Meat and fish are preserved by salt in two ways: by *dry salting*, and *wet salting*, or pickling.

Dry salting is done as follows:—Meat is cut into pieces of a proper size. The bone is removed. Then about 2 lbs. of small grained salt to 25 lbs. of meat is well rubbed in, especially to all holes and cuts; pepper and spice being added if liked. The meat is then put into tubs with layers of salt between the pieces of meat. Here it parts with its juice and forms a pickle. After a week, it is taken out and repacked in other tubs, with fresh layers of salt. It should be kept thus, for at least a month, before being used on voyages, or exported.

In Newfoundland and Shetland, cods are gutted, split, and laid in piles, with layers of salt between them. As soon as they have absorbed the salt, they are stretched out on walls, in the sun, to dry: when dry, they are said to be *cured*, and are fit for use.

Pickling.—Fish are also salted in brine, or pickled. There is a large trade in pickled herrings in Scotland. Herrings, as soon as caught, are slit open, and everything taken out, but the milk and roe. They are then washed in fresh water, and put into a tub of strong brine for 12 or 15 hours. After that, they are drained and packed in barrels, well pressed down with a layer of salt between each row, and another at the top and bottom. Small grained salt is used in curing; large grained, in packing, because it lasts the longest.

Liebig attributes the antiseptic action of salt to its

drying influence on the tissues. "Fresh flesh, over which salt has been strewed, is found after 24 hours, swimming in brine, although not a drop of water has been added. The water has been yielded by the muscular fibre itself, and having dissolved the salt in immediate contact with it, and thereby lost the power of penetrating animal substances, it has, on this account, separated from the flesh. The water, still retained by the flesh, contains a proportionally small quantity of salt, having that degree of dilution at which a saline fluid is capable of penetrating animal substances. This property of animal tissues is taken advantage of in domestic economy, for the purpose of removing so much water from meat, that a sufficient quantity is not left to enable it to enter into putrefaction." *(Organic Chemistry)*.

The greatest attention is required to the thorough salting of pig's flesh, for certain parasites, the cysticercus cellulosæ and the trichinæ spiralis, which are frequently found in pork, are killed by the salt, if it reaches them in a sufficiently concentrated form, and not otherwise. These parasites, if they escape the salting, are eaten with the pork, and give rise to painful and even fatal disorders in the bodies of their hosts. Many fatal epidemics of trichniasis have occurred in parts of Germany, in which uncooked pork, badly cured, had been eaten by the peasantry.

The preparation of *Ngapee*, a celebrated fish preserve, made in Burma, seems to be a mixture of dry and wet salting, judging from a note (iii,) p. 271, in Col. Laurie's "Ash Payee." The fish are scaled, and salted in layers, and drained in a basket under the pressure of weights. They are then spread out to dry a little, and finally pickled in jars of salt in their own juices. When the liquor is all evaporated, a very unsavoury smelling mass of fish, highly prized, is the result. The Burmese make a kind of sauce

with fish, cut up and steeped in brine for one night, and afterwards exposed to the sun till putrid. This stuff is brayed in a mortar with salt, and kept for two or three months longer until it is quite ripe for sale. It is used as a condiment and sauce. Its preparation recalls that of certain spurious forms of catsup, made with putrid livers and salt, which resembles the real article so closely as to be difficult of detection. Mushroom catsup is the extract of mushrooms, pickled in salt.

In Cornwall, the pilchard curing process is called *bulking*. The fish are salted in curing houses, great quantities of them being built up into stocks, alternate layers of salt and fish; they are allowed to remain thus for four weeks. A large quantity of useful liquid manure drains away during the curing. Finally, they are washed and packed in hogsheads, for Spain and Italy, chiefly. The Cornish pilchards closely resemble sardines, if they are not the same fish. Le Croisic, in Brittany, is the head-quarters of the sardine industry. There the little fish are caught and salted, and at the neighbouring town of Nantes, they are preserved in oil or butter, in tins. The Coast of Brittany swarms with fleets of sardine boats. It is a salt manufacturing country, and cheap salt assists the fishermen to dispose of their takes. As soon as the fish are caught, they are sprinkled with salt: and when the boats reach shore, the sardines are picked out one by one, and systematically salted over, without being gutted. They are then packed closely in baskets, in rows, and between each layer of fish, a layer of salt is sprinkled, and over all, when the basket is full, a good covering of salt is strewn. In this state sardines will keep from four to seven days, according to the weather. The fish are not gutted or scaled before salting.

Cod curing is done upon a large scale in Newfoundland,

and also in Scotland. The fish are split, cleaned, boned, pickled, drained, washed, brushed, and spread out to bleach and dry in the sun. Then they are heaped. When they effloresce with salt, or "the bloom comes out on them," as it is technically expressed, they are ready for the market. Fish salting is an industry which enriches coopers, tinsmiths, basket-makers, etc.; according as the fish are sent off to market. Pressed cods' livers, the refuse of cod oil works, are salted and exported to France, as sardine bait. This bait is highly prized by fishermen.

Salt butter for exportation contains sometimes as much as 1 lb. of salt to 6 lbs. of butter, but ordinary salt butter should not contain more than 8 per cent. of salt. Butter contains caseine and albumen, butyrin and caprin, which undergo putrefactive decomposition from exposure to air, causing the butter to become rancid. This the antiseptic salt prevents. Salt can be removed from butter by kneading the butter in fresh water, which dissolves out the salt. Even fresh butter has from half to two parts per cent. of salt added to it. Salt, for butter, must be very pure, as the least trace of magnesium gives the butter a disagreeable flavour.

The *rennet* which is used to coagulate milk, in cheese making, is the stomach of the calf, lamb, goat, sucking pig, or hare, prepared with salt. The fresh stomach is heated with dry salt, or steeped in a *saturated* salt brine, and is dried, and then hung up for eight or nine months. Afterwards it is again plunged in salt water, in which a portion of it dissolves, giving the water the curious property of coagulating milk.

The quality or flavour of cheese also depends, in a great measure, upon the amount of salt present. The taste of cheese, especially of Stilton, Rouqefort, Gorgonzala, and the like strong kinds, is a question of decomposition, and the

production of organic ethers, acetic, butyric, valerianic, caproic, etc., having different flavours. Common cheese contains about 1·8 per cent. of salt, or 126 grains per lb.

Bacon is cured with salt and brine; the latter being forced into the flesh by means of a force pump and jet. It contains, when saleable, about 3·8 per cent. of salt by weight, or 256 grains per lb.

Salt is largely used in bread making. The 2-lb. loaf contains about a quarter of an ounce of salt.

Salt is used by some Publicans as an adulteration of beer, to promote thirst. But according to the Pharmaceutical Journal, 12th January 1878, it is also formed as a natural product in brewing malt, hops, and saccharine matter. Of 24 samples examined by Dr. Rygate, Public Analyst, in London, in the beginning of 1882, two, one of porter and one of ale, were found to contain salt. The former contained 25 grains, and the latter 54 grains, of salt to the gallon. (*Lancet*, Feb. 25th, 1882.) The object of this adulteration is to increase thirst. Beer naturally contains a small quantity of salt; but not sufficient to cause thirst.

A considerable amount of salt is used up in the preparation of vegetable pickles of all kinds; soaking in brine being one of the most important steps in their manufacture. Also a great quantity of salt is required for the olive trade. It is not so much in the preparation of the olive for food, as in its subsequent preservation, that salt is used. Olives are simply preserved in strong brine, after they are "cured."

Substances which require to be boiled at a high temperature, to be cooked tender, as potatoes, are boiled in water to which salt has been added, as the boiling point is thereby raised.

Potatoes which have been plunged for ten seconds in a boiling saturated solution of salt, can be kept in store for

any length of time without deterioration, or fear of sprouting. As will be seen in the next chapter, farmers steep their seeds in salt brine to preserve them. It is also used in keeping hay, and in other agricultural operations to be later noticed.

Salt forms a hygienic and handy plug for tobacco pipes, which may be used with advantage by smokers. The bowl of the pipe should be filled about one-third with salt, and care taken, at first, not to draw the salt into the mouth with the smoke. After a time, under the influence of heat and nicotine, the salt forms a hard cake, which acts as a filter on the smoke, depriving it of its deleterious particles.

The density of brine is taken advantage of by some housekeepers to test the soundness of eggs, and of potatoes, as farmers test their wheat. If 120 grammes of salt are dissolved in a litre of water, an egg put into this solution on the day it is laid, will sink to the bottom; an egg one day old, will not quite touch the bottom; an egg two or three days old, will rest proportionately further from the bottom; whilst an egg, more than four days old, will float upon the surface. In the same way the nutritive value of potatoes has been tested, the quantity of starch being determined by means of the specific gravity of the tubers, tested with strong brine; for details, see paper by Dr. W. Schultze, Polytechnishes Journal von Dingler, Oct., 1871.

Windows.—In northern latitudes the resistance of salt solutions to freezing, even at intense degrees of frost, is taken advantage of by housewives, who smear their windows with a strong brine. This prevents the formation of ice, and the lodgment of snow on the windows, and keeps them translucent; an important matter in the winters of the north; without salt, the people would see no daylight within their houses.

Salt is also thrown on snow clad roads, and frozen streets, to keep them moist and passable for wheeled traffic. In the severe frost of Jany. 1881, the Omnibus and Tramway Companies of Paris, used up 620,000 kilos of salt, to keep their lines clear. Even though it be freezing hard, salt melts snow or ice in a very short time. It takes water from them, and forms a brine which will not freeze in ordinary frosts. The objection to the practice is that snow and ice, form, with salt, a freezing mixture, which has a temperature of 0° F. whilst melting, and subsequently the temperature of the air, as low as it may be. So that men and animals have to wade about in a freezing mixture, which chills their feet to a degree dangerous to health. The shoeless poor, whose home is in the streets, are thus in a manner sacrificed to the convenience of the rich, who however, are not free from risk, themselves. "In the tropics, on the sea coast, where the percentage of moisture in the atmosphere is high, and sea water plentiful, the deliquescent property of sea salt may be made use of without inconvenience of any kind. The hot and dusty roads of the tropics dry up very quickly, and take a great deal of watering with fresh water to keep them moist. Sea water would be more effective, and cheaper in the long run, for the purpose. Mr. A. Wanklyn writes to the Chemical News, Nov. 3, 1871, that in the summer of 1870-71, the Westminster District of London was watered with a solution of Mr. Coopers salts, similar in their action to sea salt, and in both seasons the saving in expense was sufficient to pay for the salts, and to leave a considerable profit to the patentee and the vestry. Before the salts were used, 22 water-carts were required for Westminster; whereas, with the salts, only 11 were required, and the work was done better.

CHAPTER VIII.

AGRICULTURE.

The value of salt in Agriculture seems to have been discovered at a very early period. We find references to it in ancient Chinese literature, and in the Mosaic Record. That curious quotation from Luke, xiv, 34, which has already been referred to with reference to permiorphism: "Salt is good; but if the salt has lost its savour, wherewith shall it be seasoned, *it is neither fit for the land nor yet for the dunghill,*" proves conclusively that salt was used as a chemical manure long before the Christian era. Abundant references are made to the value of salt for cattle by classical writers: but it is not, until a comparatively recent period, that we have subsequent historic records of its systematic use in agriculture. John Glauber, a Chemist of Amsterdam, who wrote many chemical works about the middle of the 15th century, was so much struck by the value of sea salt as a manure, that he obtained a patent from the Dutch Government for the sole disposal of it in agriculture. (Prosperity of Germany, English Translation in folio, London, 1689, p. 388.) Johnson's "History of the Wonderful things of Nature," 1657, p. 94, mentions salt as a good field manure. Gervase Markham, who wrote, in 1660, "The Enrichment of the Weald of Kent," speaks very highly of salt sand, salt weeds, salt water, and salt brine, as manures. Sir Hugh Platt, "Jewel House of Art and Nature,"

London, 1653, chap. 104, attributes the value of all manures, even of dung, to the salt contained in them. Lord Bacon, 1620, Nat. Hist. Cent. 6, Ext. 596, says, that "the best manure next to marl is sea sand, which obtaineth a special virtue by salt water." He also mentions the various benefits to be derived from watering different kinds of vegetables with a solution of salt. Bishop Watson, of Landaff, published an Essay in the year 1773, in which he relates that at the town of Northwich alone, the farmers purchased 3,000 tons of salt annually for agricultural purposes, although they had to pay 13*s.* 4*d.* duty per ton, and wheat was 45 shillings the bushel. About this time the agitation for the repeal of the salt tax was carried on with great vigour in England, and as the result, in 1818, a Parliamentary Select Committee sat for sometime examining witnesses as to the value of salt in agriculture. The question of the worth of salt in agriculture got mixed up with the question of taxation, and rather coloured accounts of its value as a manure were put into circulation with a view to procure the abolition of the tax. The Report of the Select Committee, 1st June 1818, vol. 5, is a mine of information on this subject. Many pamphlets were issued at the time, bearing on this question, of which Parkes' book, "A Letter to Farmers and Agriculturists," is the best. He seems to have furnished the materials for subsequent Essayists. His book also contains copious extracts from the Minutes of the Committee of the House of Commons on the Salt Laws. It is written in a warmly partisan spirit in favour of the abolition of the salt tax, and therefore contains everything which would be likely to further that object.

At the present moment the use of salt in agriculture seems to have fallen into obscurity, if not exactly into dis-

favour: and we may attribute this to the disappointed expectation of those who had used it on the faith of overwrought accounts of its value. Besides this natural reaction, salt in agriculture, as formerly certain remedies in medicine, is subject to the ebb and flow of the tide of uneducated popular opinion. The class of farmers who make or mar its popularity, are not well instructed in the necessary conditions which govern its successful application to land, and often make mistakes.

But salt, as we shall see presently, is a powerful chemical manure, which requires to be applied with great circumspection, and which does not forgive mistakes. It is the object of this chapter to point out its true value and the theoretical and practical considerations which govern its use. One reason assigned by a late writer on the subject, (R. Falk, Prize Essay, 1863,) 'why salt is despised by agriculturists,' is because it is *too common.* In the search for new and strong remedies for the worn soil, *common salt* is overlooked in favour of guano, and a host of patent manures, many of which owe their efficiency to this same sodium chloride. Salt is cheap; it is common; it is hence the Cynderella of manures, and is despised in favour of expensive compounds, which are valued almost in proportion to their expense.

One striking property of salt, which is well calculated to diminish its prestige as an agricultural manure, is the blighting effect it has on vegetation, when present in soils in excessive quantities. This has been noticed by all writers on the subject.

Excess of salt in soils appears to hinder vegetation in a very remarkable way, so much so, that salt swamps, and plains on which salt effloresces, are noted types of barrenness. A few plants, such as the Trigolochinum maritimum,

the Salicorma, the Salsolakali, the Astertrifolium, the Glaux maritima, and the Crithmum maritimum, or Samphire, etc., select saline localities, in which moisture is abundant, as salt swamps, salt springs, etc., for their growth. Of these the Samphire, Nat. Ord. Umbelliferæ, is an esculent and used for food in some countries.

The neighbourhood of the Dead Sea, the Steppes of Russia, the Trans Indus salt region, and a number of other localities in which salt abounds, might be mentioned, as striking examples of its deterrent influence on the growth of vegetation. These salt regions are barren wastes with hardly a tree to shade them. This is not, however, in these cases, so much due to the chemical operation of salt in the soil as to the nature of the soil itself, which is too rich in sand and common salt, and not rich enough in other plant forming materials; vegetation is not found there, not because it is blasted by common salt, but simply because it never had any existence there for want of a suitable nidus.

But besides this negative property, there is no doubt that salt has a directly blighting, or "scorching" effect, as it is aptly termed in old books, on vegetation, under certain circumstances. For example, salt storms, or violent winds laden with sea spray, have been known to do great harm to plant life in their course. *The Transactions of the Linnæan Society*, vol. 8, p. 207, contains an account of a salt storm, so called, *which raged for several days* in January 1803 on the East Coast of England. The most remarkable phenomenon noted in connection with this storm, was that it withered the leaves of plants and mortified their top branches for a space of *seventy miles* from the sea. The withering effect of another salt storm which occurred in 1815, in the States of New England, is noticed in the *American Journal of Science and Art*, vol. 1, p. 388. At New London, Salem,

and other places, both on the coast and several miles in the interior, the leaves of many trees appeared as if they had been scorched. The injury to plant life produced by salt storms, seems to be in direct proportion to their intensity and duration. It is a question of the *violent* application of salt spray to plants, and for a certain length of time.

There is abundant evidence, apart from salt swamps and salt storms, that salt can kill vegetation. Gardeners and agriculturists are much better acquainted with its poisonous, than with its fertilising properties. It is in common use for the destruction of weeds. Many a gardener strews the weed grown pathways of a pleasure-ground with salt, to kill the weeds, who has not the least idea of its value as a manure. Farmers employ salt in large quantities for the improvement of weedy lands. This is the first use of salt in agriculture, which we have to notice. The amount of salt required for this purpose, varies with the character of the soil and the growth of weeds, from 15 bushels of 56 lbs. each, to a ton, per acre. The details of a number of experiments made in England, in 1797, are given in Rees' Cyclopædia, article *salt*. It was found that on different lands, from 10 to 50 bushels of salt per acre, had the effect of destroying vegetation; that is from 560 to 2,800 lbs. Mr. H. Butler writes, (*Agricultural Gazette*, 1847, p. 824,) that he sowed one ton of salt per acre on six acres of old sainfoin hay, and ploughed the land after the first heavy rain. The salt in the winter reduced the weeds and crouch grass to manure. Some of these experiments I repeated on a small scale in the spring of 1881, in a private garden at Blackheath. I found that weeds required a visible coating of salt to destroy them; and that a grass plat, powdered with salt until it became white as with hoar frost, was converted in the space of seven or eight weeks into

a muddy barren waste. A solution of salt, two ounces to the gallon of water, poured on grass, and the young leaves and shoots of plants, *for three or four days in succession,* had a withering effect; but used once its effects were inappreciable. Powdered salt, also, placed on the tender shoots of roses and other plants, had not much effect, unless repeated. The weather was showery throughout. The experiments of Professor Girardin of Rouen, show that when a soil contains as much as 5 per cent. of salt, only the Salsola, Glaux, Elymus, and other sea side plants will flourish in it; and when the salt amounts to 12 or 14 per cent. even these die.

There is an analogy between animal and plant life, as regards salt, which is worth noticing as the occasion offers. Fishes, for instance, are affected like plants by the percentage of salt in water. Certain fresh water fish cannot stand the salt sea; other sea fishes cannot bear 5 or 6 per cent. of salt, in their water; and when sea brine becomes a 10 per cent. solution, as it does in salt gardens, all marine fauna die. These are observations I have made in salt gardens, where the alterations in the density of the brine and its corresponding effects on fishes, crabs, etc., can be studied with ease. At the same time the conditions of life are altered in a salt garden since, by evaporation and oxidising changes, the brine there has lost much of its oxygen.

The elder Dr. Darwin, in the beginning of the present century, attributed the blighting effect of salt upon vegetation to its strong stimulant action, destroying the irritability of the vessels of plants, by over stimulation. There is no doubt that salt is a powerful stimulant, and, in a concentrated form, a local irritant to living membranes. Excess of salt is taken up by plants and circulates as such in the sap, as shown by Parkes, who mentions an instance

in which salt effloresced on the leaves of a plant experimentally over-dosed with it. It would probably thus arrest rootlet absorption and destroy the irritability of the stomata. Besides this, excess of salt interferes with chemical and nutritious changes in the plant itself, and the normal sap reactions of endosmose and exosmose. Near London, and other large towns, some of its scorching action upon the leaves and young shoots of plants, when applied locally, would perhaps be due to the influence of sulphuric acid in the atmosphere liberating the hydrochloric acid from the salt.

It should be observed that other mineral fertilisers besides salt are capable of injuring plants if presented to them in too strong a form: thus, one part of ammonia in 1,500 is injurious; whereas according to Dr. Geubel, salt may be used in solutions of 1 part to 200 with benefit. (Falk R. "Essay, on salt," p. 11.) It may be safely used, as I have tested, 1 part to 80. On the other hand it appears possible for plants to get accustomed to salt by natural adaptation. Dr. Holub, "Seven years in South Africa," noticed that arrow grass and dense brushwood grew up to the edges of some of the salt lakes; whilst round about, in the very thickest of the grass, were found miniature salt pans.

Closely allied to the blighting action of salt is its vermicide property; the difference is rather in the subject than in the action. Salt destroys slugs and snails, grubs, caterpillars, worms, and soft creeping vermin of all kinds. It appears to act in the first instance as a local irritant. Sea bathers know that strong solutions of salt irritate the eye. Salt has been rubbed into wounds to enhance the suffering, etc. Its emetic action is due to local irritation. So also its anthelmintic effect on round worms, in the intestinal canal of human beings. It is in common use as

an irritant in physiological experiments on frogs. Its action may be studied on the familiar leech, induced to abandon its victim by a pinch of salt. The leech shrinks from its bite, and writhes, with pain, apparently. It empties itself of blood and exudes slime; and if much salted, it gradually withers away and dies. It is observable that worms, slugs, and snails, killed by salt, in the open, leave much slime in their tracks.

Some few unfortunate worms that I have treated with a pinch of salt, with a view to study this question, wriggled, exuded slime, got thin, blanched, and died in a few minutes. A withered up, dirty white appearance, characterised the dead forms of various red worms so treated. The impression left on my mind was that the salt acted as it does on meat, absorbing moisture and withering up the worm. Wherever the salt touched the worm, a white spot, like a caustic mark, formed at once. The slime showed with test paper an alkaline reaction. I have also observed that salt, in the dry state, produces no effect whatever upon insects, and coleoptera, as a class; since unlike worms and snails, they furnish no moisture for the dissolution of the salt. It is necessary to attack these, bugs, beetles, and the rest, with a strong solution of salt.

This vermicide property of salt renders it of great value to the farmer, the planter, the florist, and the market gardener. It is one of its most important uses in agriculture. Mr. Fenn, of Cheshire, in 1797, *(Rees' Cyclopædia, salt)* noticed that 10 to 12 bushels of salt per acre destroyed snails or caterpillars. Mr. H. Butler, whose experiments have been detailed, noticed *a total absence of wire-worms* in the fields salted by him. These worms, he tells us, destroyed a large portion of the corn sown in his neighbourhood. Mr. J. Buck, referred to in Johnson's *Essay on Salt*, as a

gentleman who had tried the vermicide property of salt on some hundreds of acres of wheat, states, that he sowed the salt *in the evening*, with a common hand shuttle, some 4 or 5 bushels to the acre, and that he found the casts marked with dead slugs in the morning. Mr. J. Slater, *(Johnson's Essay.)* saved, by the use of salt, a crop attacked by slugs and worms; whilst neighbouring crops, *not salted*, were completely destroyed by vermin. The late Mr. Mechi, *(Agricultural Gazette,* Nov. 23, 1847,) bears testimony to the value of salt as a vermicide. His swedes, when salted, escaped the ravages of the cockchafer grub. Mr. Lennox Bigger, wrote to the *Agricultural Gazette,* Dec. 4, 1847, giving the results of his experience of twenty years use of salt in agriculture. He sowed it on grass land "and to satisfy himself as to any effect it could have, in the first instance, he turned up the sods which had been ploughed down, and found no trace of the salt, for it had all melted away by the damp of the grass or the atmosphere; and in place of it he found slugs, snails, worms, clocks, and every insect to which England's climate is usually subject, lying dead." Half a ton an acre is the least proportion that he would recommend. He says that the vermicide property of salt can be easily proved, when pulling up cabbage stalks in a garden. If a few handfulls of salt are sprinkled over the bed "in less than a quarter of an hour, you may observe that slugs, snails, and worms have dragged white lines after them, and at the end of each, you will find the insect (sic.) lying dead." Mr. Beardsley, of Shipley, writes to the *Daily Mercury,* 1847, that he had been using salt for 10 or 12 years. He sows it broadcast, as a top dressing, after sunset, in the months of April and May, 3 or 4 cwt. to the acre. He says, "if the young plants should appear sickly and turn yellow, it is a true sign that the slug and wire-worm are making ravages upon them, and I have

always found that the application of salt exterminates these destructive insects. I believe that slugs, etc., will not germinate in land so treated." We have here abundant evidence, on the part of practical farmers, of the vermicide properties of salt. It is a question, how long this vermicide effect, lasts in the soil? Judging from the grass plat, before-mentioned, salted by myself, I should think not more than two months. I dug up a part of it at the end of three weeks, and found no living, but several dead, worms. I dug it up again about a month afterwards, when the grass was quite withered, and found some worms in it; but these were at the edge, and certainly they were not as numerous as they had been.

Several experiments have been tried in France with a view to the destruction of phylloxera, the deadly enemy of the vine, with salt, but so far with negative results. Salt has been applied to the roots and rootlets of the vine, in the solid state, rubbed on; and in addition, a pound of salt has been buried in the roots of the tree. Trees, so treated, survived the phylloxera, and were living some years afterwards, when last seen by my informant, Capt. Du Temple, of the Messageries Maritime; but they looked sickly and were not bearing. Other trees, in the neighbourhood, untreated, had been long dead. Of ten trees salted by himself, in the manner described, five quickly died. The other five bore magnificent crops, and attracted much attention; several bunches of the grapes they gave, weighed 2½ lbs. each. Unfortunately for the value of the experiment as regards salt, sulphate of carbon was used in the last case, in combination with salt. Still the general impression was that salt had worked well.

I have tried the effect of a saturated solution of salt on white ants in India. If removed from their nests and placed

in the brine, it has a sickening effect on them, and many of the weakly ones die very quickly. But strong brine injected into ant-hills, simply causes a collapse of the earthy walls, which appear to lose cohesion at once. Out of the debris, the white ants crawl to a place of safety, little harmed, as the brine is absorbed by the fine earth. They often return the same day, and if again dislodged with brine, return again, but they evidently dislike it, and retire vanquished if this treatment is persevered with.

The vermicide property of salt should attract the attention of Coffee planters. There can be little doubt that, properly applied, it would prove fatal to the Coffee borer, a species of grub, which does serious damage to coffee properties.

In another direction also salt might prove of great service to planters. It is an effective poison, not only for the full-grown bug, or fly, or grub as the case may be; but also for their seeds and germs; and for the host of parasitic fungi which prey upon the lives of highly cultivated plants. It seems to be a natural weapon placed in the hands of the farmer and the planter to enable them to contend with the parasitic diseases of plants, such as smut, rust, *hemelia vastatrix*, or the coffee leaf parasite, *phylloxera*, or that which attacks the vine; and the rest.

In some places, wheat, barley and other seeds, are steeped in salt brine, before sowing, to kill fungi and preserve the seed in the ground from the attacks of grubs. Salt completely preserves wheat from the smut, and it is said in the "Natural History of Common Salt" S.P.C.K. to affect a cure in the case of all plants diseased with smut. The brine should be sprinkled on with a brush, from a solution containing one pound of salt to the gallon.

Sir J. Sinclair, in his evidence before the Committee of

the House of Commons, On the Salt Laws, April 21, 1818, stated that, in East Lothian, the farmers steeped the sowing wheat in a strong solution of brine, and stirred it up well; all grains which floated to the surface of the brine after this treatment, they rejected as unsound. Salt also arrests mildew in wheat, and the formation of the poisonous ergot of rye. Certain cautions are required as regards the use of salt as a vermicide, both as to its quantity, the time of applying it, and the manner of applying it. We have already seen that from 560 lbs. to one ton of salt, per acre, will, according to circumstances, suffice to destroy weeds; which, as every one knows, are hardier than cultivated plants. If, therefore, the crop is on the soil, at the time salt is put down as a vermicide, it could not safely be used in larger quantities than 400 lbs. to the acre. But if put down before sowing time, larger quantities of salt can be used, in proportion to the interval between sowing the salt and sowing the seed; for as we shall presently see, salt does not remain very long, as such, in the soil. The best time to apply salt as a vermicide, seems to be the evening, judging from the observations of practical farmers. Whether the victims are at that time at rest and near the surface, or otherwise taken at a disadvantage, is not known; but the night dews clearly assist in forming a strong solution of the salt, which flows into crevices, which granular salt could not reach. The manner of applying salt as a vermicide, *i.e.*, whether in solid or solution, sown broadcast, or applied to particular trees, will vary with the object in view, and the means at the disposal of the agriculturist. This need not detain us. It appears to be the safest plan to destroy weeds andvermin at one salting, four or five months before the sowing, so as to kill two birds with one stone, and avoid injury to the crop. Farmers should bear in mind

that the researches of Darwin on "The Formation of Vegetable Mould by the Action of Worms," prove that worms are often their friends. They bring soil to the surface and bury stones; and they also in the course of time, pass large quantities of mould through their intestinal canals, improving its fertilising properties very much. These, however, appear to be processes of more value for the reclamation of waste lands, than for those actually under cultivation, where speedier results are required.

When applying salt to the parasitic fungi which inhabit plants, care must be taken not to overdo the poisoning so as to injure the plant itself. It is repetition of effect, as we have already seen, which seems to enable salt in solution to injure plants. For large and hardy shrubs, such as the coffee tree, a solution of salt of the strength of one pound to the gallon may be used; for delicate plants, a weaker solution in proportion, down to three ounces. The drenching or moistening with salt cannot safely be repeated at shorter intervals than twice a week: nor, in any case, can more than about 400 lbs. to the acre be used, for reasons already given.

So much for the poisonous properties of salt and the benefits which agriculturists generally manage to draw from them. With the exception perhaps of the application of salt to parasitic diseases, there is no lack of knowledge on this subject. But the case is far otherwise as regards the use of salt as a chemical fertiliser or manure. It is not in the same category, for reasons of prejudice, already noticed, and also from sheer ignorance. Yet this is its most important function in agriculture. Before proceeding to consider the direct action of salt upon plant life it will be necessary to notice a property that it possesses by virtue of its marine origin which renders it a valuable component of the soil. That is its deliquescence.

We have already seen that pure sodium chloride is not deliquescent: but there is no question of purity as regards agricultural salt. The refuse salt of salt mines, and the worst description of bay salt, are those preferably used, for economical and other reasons. This salt contains more or less magnesium chloride, and it is to this source it owes its deliquescence. It is this which recommends it to the practical agriculturist. By virtue of its deliquesence it absorbs moisture from the atmosphere and keeps the soil moist, cool, and soft, in dry hot weather, when land would otherwise get hot and hard as iron. It also directly assists in the nourishment of plants by providing the water required to dissolve their food. *Plants can only take up their nourishment in solution;* hence this is an important point in favour of salt manures.

In the severe frosts of northern climates salt is often sprinkled on lawns and pleasure-grounds to keep the grass from being destroyed by frost bite. We have seen it similarly used for, for keeping snow off roads. The theory is a bad one. If it were rigidly carried out, it would kill the grass. The brine formed by the deliquescent salt will not freeze; it will prevent the formation of hoar frost; it will even cause snow to melt as it falls; but it will absorb an intense degree of cold, and penetrating to the roots of the grass it will carry down there the hard frost it was intended to ward off; whilst at the same time it does not protect the surface from cold in the least. It acts like the frost carrier of an ice-machine, combining intense cold with the reactions of fluidity. Hoar frost and snow are the natural protectors of grass, and shield it, especially the latter, from the severe frosts which would kill it. In practice the use of salt is attended with no bad results—but rather the reverse. Too little salt is used to influence tem-

perature effects; but enough is used to do good as a manure.

We may now consider how salt acts as a fertiliser. Here also there is an analogy between the use of salt to plants and animals. Salt is a stimulant to plants, causing increased nutritive activity in the tissues; just as it stimulates digestion in animals. Without being a food itself, it assists in the assimilation of foods, which could not pass into the system without its aid. This is its chief office, and that which will have to be considered with most detail. It is antiparasitic, as has been noticed already. And it influences to some extent the regular flow of endosmose and exosmose in the sap. It also confers upon water valuable solvent properties.

Though excess of salt destroys plants by over stimulation, in small quantities it has a healthy stimulant effect. It appears from the results of experiments, made by Dr. Priestley, that sprigs of different plants and vegetables lived longer in salt water, containing 2 grains to the ounce, than in fresh water; and though they died in water containing 12 grains to the ounce, they flourished for a short time in this, and water of intermediate strength, more than in pure water, as if under the influence of a stimulus.

These experiments, which I have repeated, leave no room for doubt as to the stimulant effect of salt, since there is nothing else present to complicate the matter. In soils, there are other salts, with which sodium chloride is capable of undergoing a double decomposition, advantageous to plant life. But, not so in the flower vase; neither is there time for such chemical change. A little salt in the artificial compost used for potting flowering plants, is found to enhance the bloom and brilliancy of the flower.

These are experiments which may be made, with advant-

age, in floral displays. It will require some practice, however, to determine the best proportions of salt in solution to make the most of different kind of flowers.

It is upon grass lands that the stimulant effects of salt have been most noticed. It was probably, in the first instance, the luxurious growth of grass, on low lying meadows, occasionally flooded by the sea, which drew the attention of agriculturists to this subject. In *Phil. Trans.*, vol. 31, mention is made of a salt storm which occurred in England in 1703. It was particularly noticed that for twenty miles inland, peas, beans, but especially grass and grazing cattle, were much improved after the storm. This storm was, no doubt, less charged with salt, than those later, *scorching* storms, already noticed, or it did not last so long.

Thomas Hitt, (*Treatise on Fruit Trees, London,* 1768, p. 17,) tried salt in solution on grass land which had dried up in summer, so that cattle had to be taken from it for want of grass. He watered patches of it, one with a gallon of spring water, another with a gallon of water containing one ounce of salt in solution, a third with a gallon of water holding two ounces of salt, and a fourth with three ounces of salt to the gallon. The water holding one ounce of salt produced excellent results; that with more salt burnt up the grass, from which he concludes that salt was in excess. In this case the grass was already moribund from drought, and so, very little salt sufficed to kill it.

Salt, consigned to the earth, loses in time its characteristics. After a time, which varies with different conditions, it undergoes a double decomposition in the soil resulting in the formation of chemical compounds, useful to plant life. It could not otherwise be used as a weed destroyer; for, if it maintained its injurious influence on vegetation, the land would be lost to agriculture. There is reason to believe that under

ordinary circumstances from three to five months suffice to cause a very material diminution in the quantity of salt, although some of it may still be found in the soil, it is said, for five or six years. The experiment, of farmers on weedy-land, show that land, which will not, when freshly salted, support a weed, becomes, after four or five months, more fertile than ever. Salt is especially useful on calcareous soils; and all soils contains more or less lime. A mixture of salt and lime in the presence of earth, under ordinary conditions of heat and moisture, gradually breaks up into two new compounds, *viz.*, calcium chloride and sodium carbonate. The equation is as follows: $2\,NaCl + CaCO_3 = Na_2\,CO_3 + CaCl_2$. The fertilising element of the salt is set free as soda, whilst the chlorine combines with lime to form calcium chloride, a most deliquescent substance which powerfully attracts moisture to the earth. The carbonate of soda, absorbed by the humus, forms probably a humate of soda, and remains in the soil; whilst calcium chloride drains away in solution. Sodium carbonate is a chemical food required by plants. It has, moreover, a tendency to come up to the surface, where it is most required. It effloresces. It gives a white powdery appearance to the surface of marly salt pans; also to the cement of old buildings near the sea, acted upon by salt air. Sometimes it gathers on the surface of large tracts of country in such quantities as to unfit them for cultivation. Bertholet says of the sodium lakes of Egypt, and the Rheh lands of Northern India, "All the lands where we now find soda were once impregnated with sea salt. Where the soil is sandy, one finds sodium chloride associated with but little carbonate. But where, on the contrary, the soil contains much lime, is humid, and there is salt, we get a quantity of carbonate of soda."

Bicarbonate of magnesia, even at ordinary temperatures,

is capable of decomposing sodium chloride with the resulting formation of magnesium chloride—an intensely deliquescent salt which attracts moisture and drains away—and sodium carbonate which remains. This is a very important reaction to bear in mind in dealing with dolomitic soils, or those containing much magnesium limestone. Such soils are greatly improved by salt. Acted upon by oxide of lead, lime carbonate and iron, in the presence of heat and moisture, salt is very slowly decomposed, yielding the *oxide*, or carbonate, of sodium, both valuable fertilisers.

By weathering alone, also, that is by the action of the oxygen and carbonic acid of the atmosphere, there is reason to believe that salt is sometimes oxidised, or converted into sodium carbonate. (See, Maundrell, the Valley of Salt, Gebul, p. 43.) Walls built with lime, mixed with unwashed sea sand; or with lime slaked with brackish subsoil water, found on the coast; or even exposed to the salt atmosphere; all, in different degrees, effloresce with sodium carbonate, mil-dew with calcium chloride, and fall into ill repute. Sodium chloride combines with ammonia, or its carbonate, forming ammonium chloride and sodium carbonate. It thus fixes and prevents the loss of valuable ammonia, whilst furnishing new compounds beneficial to vegetation. Further, Bousingault shows that salt has the power of setting ammonia free from soils containing humus.

Quite as important as its chemical reactions is its solvent power upon certain components of the soil. As before noticed, plants can only feed on solutions. Liebig, great authority on these questions, says, in effect, (Letters on Modern Agriculture, p. 53-60) that numerous experiments have shown that common salt is a fertiliser of grain crops of considerable power, and that it increases the value

of ammoniacal manures in a very remarkable way. The General Committee of the Agricultural Society of Bavaria, made a series of experiments on barley cultivation at Bogenhausen, near Munich, with ammoniacal manures, including the carbonate, phosphate and sulphate of ammonia, alone, and with the addition of common salt. The experiments were very conclusive of the value of the common salt, mixed with ammonia, as a manure. Mixed with carbonate of ammonia, sodium chloride doubled the produce of grain; and with nitrate of ammonia, it raised the produce of corn 90 per cent. and of straw 120 per cent. It was also found that it increased the value of nitrate of soda, as a manure, to use it in combination with common salt in the proportion of two-thirds of the former to one-third of the latter. In the ammonia experiments about half as much salt was added to the quantity of ammonia used. As neither sodium chloride, nor chlorine, appear to enter, as elements, in the structure of plants, though often found in their ashes, the explanation of their fertilising power must be sought for in their action upon the soil. Here we touch upon another great indirect benefit of salt as a manure. It is probable that like carbonic-acid water, they assist in the assimilation of earthy phosphates by dissolving them for plants. Earthy phosphates, such as bone dust, are ordinarily dispersed through the soil by the solvent action of carbonic acid in solution. But solutions of the salts of ammonia, of sodium nitrate, and of sodium chloride, also possess this power. To confine ourselves to sodium chloride.

Direct experiments prove that 220 lbs. of common salt in 11,000 gallons of water will dissolve $3\frac{1}{3}$ lbs. of calcium phosphate, or $8\frac{1}{3}$ lbs. of magnesium phosphate, or $13\frac{1}{2}$ lbs. of the ammonia magnesium phosphate. We see from this that salt gives water a solvent power on earthy salts

which it would not otherwise possess. It is noteworthy too, that experiments show that the solvent power of the water does not increase in direct ratio with the amount of salt in solution, but rather the reverse. Largely diluted solutions act the strongest. Common salt remains for a considerable time in the soil, being very slowly converted into chloride of lime or magnesia; it should not therefore be reapplied until its effects pass away. It takes up earthy phosphates, where in excess, and distributes them where required; furnishing the rootlets all round with phosphate in solution. The same remarks apply to the ammoniacal salts and sodium nitrate. These manures are chiefly required where earthy phosphates already exist, applied in the shape of bone dust. Bones are deficient in salt, the ash only yielding from 0·7 to 1·5 per cent. sodium chloride.

Salt is also a powerful solvent of silica, so necessary to the hard parts, the inorganic structure, or frame work of plants. It has been long claimed for the use of salt manure that it gives a finer and a stronger stem to cereal plants, and tends to prevent their lodgment by wind and rain. We see in its solvent action upon silica the key to this result.

Finally, salt assists the oxidation and solution of iron, as has been already noticed in connection with physiology, and as will be noticed again in reviewing the cause of redness in salt pans. A penknife wetted with sea water illustrates this property: also the rusty iron work of shipping, and sea shore iron structures. In Madras, what with heat, moisture, and salt, iron oxidises at such a rate that it is almost impossible to keep a bunch of keys clean.

Such is the state of the case as regards the *reactions* of

salt upon the soil. The question now arises whether is salt, as such, of any direct use to plants, beyond its stimulant action? Are plants capable of using sodium chloride in any way, and do they require it?

Some authorities are of opinion that salt is of little use as a direct chemical manure; that is to say that sodium chloride, as such, is not necessary to the building up of plants. Here again analogy may perhaps be of some service to us. Animals derive no nourishment from salt; it is in no sense a food, but still it is an important item in their dietary for reasons which have been given at p. 119, et seq. It is true that the majority of these reasons do not hold good as regards plants; but some of them, such as the stimulant and antiseptic action of salt, its influence on cell changes, its solvent action on protean compounds, and its influence on endosmose, have a place in plant physiology. It should be noticed that several of the protean compounds which are characteristic of animals, have their analogues in plants. The gluten of wheat has the same composition as animal fibrine, and has been called vegetable fibrine; the legumen of peas, beans and other leguminosæ, is identical with the caseine of milk; and the albumen of plants is precisely the same as animal albumen. These are rendered soluble by salt. Salt may have other uses in the economy of plant life with which we are unacquainted. No one imagines that our knowledge of the subject is complete. At any rate, salt, or its constituents, sodium and chlorine, are found, more or less, in the ashes of the majority of plants which have been analysed; and, as would be required of an agent concerned in the growth of plants, it is found in larger quantities in growing than in mature plants. The analyses of Schulze show that in early stage of growth, one-eighth of a plant consists of sodium and chlorides, *(Falk R.*

Salt in Agriculture, p. 6). Chemical analyses attest the presence of salt in enormous quantities in the ashes of certain plants. The cochlearia of the sea shore, contains 68·70 per cent. of salt in the ash. Asparagus, which ranks as a marine plant, grown in certain soils, yields as much as 24·33 per cent. of salt in the ash. Other marine plants are similarly constituted as regards salt. The researches of M. Ch. Mène, published in the "Revue Hebdomedair de Chimie, etc.," Paris, Nov. 7th, 1872, prove that sodium chloride is present in the common run of household vegetables, as the radish, chicory, beans, lentils, tomatoes, lettuce, peas, water cress, cauliflower, cabbage, onion, spinach, celery, artichoke, asparagus, etc.; also in some fruit, as the pear and fig. The analyses are given in full, and show that all these alimentary plants contain chlorine in the ash, in amounts varying from 0·5 to 3 per cent. Lentils contain 5·30 per cent. and chicory, the most saline of all, 32·160 parts per cent. Other chemical analyses show the presence of salt in the ordinary run of cattle foods; and these are the two classes of plants which have been most thoroughly analysed. It is present in turnips, carrots, mangelwurzel, clover, sainfoin, aud lucerne. It is also present in potatoes, wheat, chaff and straw. It is especially found in the leaves of bulbous plants, and Dr. Augustus Volecker remarks (*Journal Agricultural Society*, vol. 25, 1864,) that by keeping the leaves in a full healthy condition it contributes to a large growth; for it is through the medium of the tops that the roots assimilate organic food and gain in substance. It is probable that salt is employed in the assimilation of the organic food of plants as in animal digestion. There is reason to suppose that under certain conditions of soil, soda is capable of replacing potassium in plants. Indeed, this has been long since noticed in Balfour's Botany. He

says of plants: "Those growing near the sea, have a large proportion of soda in their composition, whilst those growing inland contain potash. Various species of salsola, salicornia, halimœnenum, and kochia yield soda for commercial purposes, and are termed halophites (αλς, salt, and φυτον, plant.) The young plants, according to Güebel, furnish more soda than the old ones. There are certain species, as Armeria Maritima, Cochlearia Officinalis, and Plantago Maritima, which are found both on the sea shore and high on the mountains, removed from the sea. In the former situations, they contain much soda and some iodine; while in the latter, according to Dr. Dicke, potash prevails and iodine disappears."

Mr. Dixon has lately analysed some of the so-called salt bushes of Australia, which are fattening fodders, much relished by sheep, especially in times of drought. The most striking fact brought out by these analyses is the large quantity of mineral ash. The average ratios of total ash, potash or common salt, in seven or eight samples, to digestible matter, taken as 100, are 47, 9·538, and 7·689 respectively. Two contained a very large proportion of common salt, *viz.*, "oldman salt bush" (the most prized by graziers) which gave 15·403 in the relation just specified, and "small salt bush," 14·590. (*Journal and Proceedings of the Royal Society of New South Wales for* 1880.)

Professor Johnstone, gives the following analyses in Farmer's Almanac, 1848, p. 23. He found in:

One ton	mangold bulbs,		5·29 lbs.	salt.
Do.	turnip	do.	1·49 „	do.
Do.	carrot	do.	1·42	do.
Do.	mangold leaves,		12·82	do.
Do.	turnip	do.	0·88	do.
Do.	carrot	do.	2·11	do.

Professor Way, (*Johnson's Essay,*) found in one ton of peas 2·15 lbs. salt; in 2,989 lbs. of pea straw, 23 lbs. salt; and in 2,270 lbs. bean straw, 13·86 lbs. salt.

Mr. G. Sinclair, (*Prize Essay on Salt,* 1820,) states that of two samples of wheat, one grown on soil salted with 44 bushels to the acre, the other not salted at all, the first or *salted* gave, on analysis, $\frac{1}{4}$ gr. of salt to 1,450 grs. of wheat. and 4 grs. of salt to 1,450 grs. of chaff; the second or *unsalted* gave $\frac{1}{6}$ grs. of salt to 1,450 grs. of wheat and $2\frac{3}{4}$ grs. of salt to 1,450 grs. of chaff.

If the foregoing analyses are correct, and there is no reason to doubt them, it is impossible to escape the conclusion that salt, as such, is of some *direct use* and benefit to the plants mentioned, otherwise it would not be found in them. It is right to state however that but little salt is found in the seeds of cereals generally; and it is absent from most grasses.

Before proceeding further it will be well to review briefly the direct action, and the indirect re-actions of salt as a manure. In the first place there is its over-stimulant action on plant life, causing the death of weeds. Then there is its vermicide property, which cuts two ways. There is the destruction of the parasitic host of living things that prey, each in their turn, upon the seed, the growing plant, the blossom, and the fruit; and this is by far the greatest merit of salt as a vermicide. And there is also the restoration to the soil, in the manure of these dead organisms, of the nourishment which plants have need of; which is at least a measurable advantage. The attraction of moisture to the soil, referred to under the head of deliquescence, is another direct benefit conferred by salt on vegetation. Then there is its stimulant action proper, renewing the vigour and health of plants. There are the chemical changes it undergoes

itself, and causes other constituents of the soil to undergo, resulting in the formation of sodium carbonate and sodium oxide, valuable fertilisers. There is its important action upon ammonia, developing it from the humus; and seizing, and fixing in the soil, volatile ammonia and its carbonates. There are its solvent powers on lime phosphate, magnesium phosphate, and the ammonio magnesium phosphate; on silica, and on iron; with their consequent marked effects upon vegetation and its character. Finally there are the physiological actions in the interior of the plant itself, which have just been noticed. The statements regarding the properties and re-actions of salt in the soil are not the subject of any controversy. They are generally admitted; and as far as they go, they give salt the character of being an artificial manure of considerable power. Moreover they have been brought to the test of actual practice, and have been amply confirmed by numerous experiments; many of them of a scientific nature; others the rough experiments of practical farmers. For the details of the greater numbers of these experiments, I must refer the reader to the special works on salt in agriculture. Liebig's and others, which have been and will be quoted in the course of this chapter. There is not room for them all in a comprehensive work on salt of this kind. I will, however, introduce a sufficient number to show the substantial nature of the claim, which salt has, to be considered a valuable adjunct to field manures.

Mr. J. Hannam, (*Journal Royal Asiatic Society*, vol. 5, p. 276,) gives the details of the following experiments. The soil was a moderate limestone, worth 24 shillings an acre. He applied the manures as a top dressing, on the 2nd May 1842, which was not a good time for the salt: too late in the season.

Manures.	Quantity	Cost. £. s. d.	Gross produce Grain Bushel.	Straw Stone, lbs.	Weight per Bushel, lbs.	
Nothing	...	...	37·3	146·4	40½	Hopetown Oats.
Sodium Nitrate 6 st. and Salt 12 st.		1 2 1½...	43·1	168·0	40	
Nitre	8 st.	1 16 0 ...	41·6	166·4	40	
Rape dust ...	1½ qr.	1 13 9 ...	41·0	160 4	40	
Salt	24 st.	0 9 0 ...	44·0	171·4	41	
Nothing	...	...	37·42	194·4	56	Barley
Salt	24 st.	0 9 0 ...	48·84	226·4	57	
Soda Nitrate... 6 st. and Salt...... 12 st.		1 2 1½...	47·84	237·2	56	
Nitre	8 st.	1 16 0 ...	48·58	245·10	55	
Rope dust......	1½ qts.	1 13 9 ...	48·08	232·8	55½	

Similar experiments made with wheat were indecisive in their results. The salt proved better than nothing; and better than sodium sulphate: but inferior to sodium nitrate, and nitre. Mr. G. Sinclair, the auther of an *Essay on Salt*, wrote to the Board of Agriculture, 25th February 1820, the result of his experiments carried out in April 1819, on silicious soils as follows:—

Barley *without manure*	gave 12 Bshl.	per acre	of seeds	weighing	43½	lbs.
Do. with 12 Bshl. salt	do. 28¾	do.	do.	do.	43	do.
Do. do. 33 do.	do. 28¼	do.	do.	do.	44¼	do.

Mr. Beardsley, whose use of salt for 10 or 12 years has been referred to, says, "I have found that my yield of wheat is four bushels to the acre more from salted than from unsalted land, when all other circumstances have been precisely the same; and I also find that where salt has been employed, I get a much bolder, brighter, and heavier sample of wheat; and I have been entirely free from rust, blight, and smut, ever since I have been using salt."

The details of a number of agricultural experiments made

in 1804, are given in *Rees' Cyclopædia*. The soils are also given. These experiments are in favour of salt as a manure. It is particularly noticed that salt prevented scabbiness in *potatoes*. In unsalted beds, the potatoes suffered much from scabbiness. There is a report on the use of salt as a manure for *turnips*, in the 27th vol., *Annals of Agriculture*, by the Rev. J. Allan, 1791. Ten bushels of salt per acre was the quantity used; and it is stated that the soil was so poor the turnips failed entirely except where the salt was put down. In the following year, salt was put down at the rate of 20 bushels an acre, with the result of a plentiful crop of turnips; two ridges that were not salted, failed totally. In 1793, worn out land was salted with 25 bushels an acre, with like success. Details are given of *flax* crops, much improved by salting with five bushels to the acre.

Mr. Forbes of Elgin, manured mangolds with salt up to *two tons* an acre with excellent results! Mr. J. Wallington of Warwickshire, remarks, (*Johnson's Essay*,) that he used salt, hoeing it into a good sandy soil at the rate of half a ton an acre. "When I first used salt, I frequently left a portion of the field as a criterion, and found that in the first instance the wheat grew slowly in the salted ground, but as the spring advanced, it strengthened and surpassed the rest, and at harvest time, it was much stronger and clearer in the straw, and free from rust and mildew, and the produce and quantity decidedly the best." The late Mr. Mechi, whose efforts to improve agriculture in England are well appreciated, says, that salt is a good manure on dry, light, well drained soils. He says, that salt removes the effluvia of dung very quickly; and that it blanches the straw of cereals, giving them a whiter caste. Bertholet, Way, and Voeleker, also notice the action of salt in strengthening and brightening the straw. Johnson refers to it in his Essay.

Mr. Lascelles, Manager, Moyar Coffee Company, (Limited,) in his book, *The Nature and Cultivation of Coffee,* writes of manuring, that a compost unequalled in its effects may be made by mixing coffee pulp, wood ashes, and common salt, with a large quantity of straw, weeds, grass, or other vegetable matter, and applying them when thoroughly decomposed. He also observes that watering coffee pulp, covered with leaves and wood ashes, with salt water, forms a valuable manure.

These illustrations of the practical benefits derived from the application of salt to the soil by no means exhaust the series of experimental results which can be quoted in favour of the view that salt is a good fertiliser; but they will probably suffice to carry that conviction to the mind of the reader. Other experiments are, however, on record, which must be noticed, whose results seem to contradict this view, and there are some agriculturists who consider that the practical question is still a matter of controversy.

Before noticing the experiments upon which those who hold salt of indifferent value rely, we must examine the conditions which should control the application of salt in agriculture, for it will be obvious to every one acquainted with its powers, that it is not a fertiliser which can be employed safely by the rule of thumb. Experiments which do not adhere to all the conditions necessary to success can be considered of little value.

Salt manures often prove disappointing, or even injurious, because put down in localities already salt enough by nature: or on wet heavy land; or in too large quantities; or in insufficient quantities; or repeated too often; or in too concentrated a form; or in the wrong place; or at a bad time. As regards the nature of the soil, it should invariably be analysed, at least roughly, as regards the presence

of salt, before salt is mixed with it. There is always a presumption that the soil is saline enough for agricultural purposes near the sea; for the spray of the sea, rich in salt, is caught up by the winds and carried for miles inland. Maritime districts in this way always receive an appreciable, though minute, quantity of salt. Sometimes, as we have seen, the salt from this source reaches excessive proportions, in consequence of storms. The effects of the salt storms which occurred in England, in 1703 and 1803, and in America in 1815, have been described. A similar storm raged in England in 1804; and Sir J. Banks noticed another in Lincolnshire some years previously. (*Trans. Linnaean Society,* vol. 8, p. 207.) Admiral Fitzroy drew attention to salt showers in the Barbadoes.

Mr. J. H. Gladstone, points out, (*Nature,* vol. 25,) that sea froth, thickened by the destruction of laminaria, forms balls, which are carried inland by storms. He saw a piece of ground, 50,000 square yards in extent, covered with about ten feet thickness of this foam. It would appear, therefore, that islands are less in want of salt manure than continents; and some doubt must always attach, in consequence, to the value of insular salt experiments as proving the inutility of salt manures. On the other hand, hilly districts in the interior of Continents, and the well washed table lands of continental mountains, are supposed to be peculiarly in want of salt, yet from such places we have no experiments to record.

As regards soil, there is a general consensus of opinion that salt should not be used on clay soils, or even on heavy, or ill drained soils. From the great attraction for moisture which refuse salt has, it cannot be used on lands which are naturally heavy and wet, for it tends to sodden them.

In the *Journal of the Agricultural Society,* vol. 25, 1864,

Dr. Augustus Volecker says, "observations on a large scale have convinced me that the nature of the soil has a great deal to do with the success or failure in all cases, when salt is tried as a manure." His experiments in 1862, were with mangolds on a heavy clay soil, and were negative in their results: but he says, "on light sandy soils, if my experience teaches me true, it is generally applied with great success." In 1863, Dr. Volecker again experimented with salt as a mangold manure on light sandy soil. These experiments were conducted in a thoroughly scientific manner, the analyses of the soil and subsoil being given, the total number of roots, total weight of roots, number and weight of blighted and sound roots, separately, and the weight of leaves per plot being given. The general tenor of the experiment was that salt had a very beneficial effect upon the crop. It specially promoted the development of the leaves, which averaged 7 cwt. per plot of $\frac{1}{20}$ acre, on the salted land, as against 5·2 on the unsalted land. Professor Volecker states that salt checks the tendency which roots have on light sandy soils of passing too rapidly through all the stages of growth: and that by keeping the leaves in a full, healthy condition, it contributes to a large produce, for it is through the medium of the tops that the roots assimilate organic food, and gain in substance. He recommends about 5 cwt. of salt per acre.

Discretion is required as regards quantity. The amount of salt required will vary with the nature of the soil, and the crop; lighter soils wanting more than those that are heavier; and bulbs, etc., more than cereals. Mr. Forbes, (*Gard. Mag.*, vol. 8, p. 82,) used from half a ton to two tons an acre. Mr. G. Sinclair, (*Essay on Salt Manure,*) used up to 1½ tons, per acre, for wheat and barley crops, with advantage. Mr. J. Hollinshead of Lancashire, who devoted 20

years of his life to the study of this subject, and who wrote a *Pamphlet on Salt*, 1800, p. 5—10, says, that his experiments with *barley* show that salt gradually increased its good effects as the amount was raised to 16 bushels per acre, and as gradually diminished in its good effects, with each fresh increment of salt from 16 to 40 bushels per acre, at which point vegetation was arrested. Johnson recommends about 20 bushels per acre, or half a ton. This seems to be the best amount; but there are instances of salt having been used with advantage in quantities varying from 560 lbs. to two tons per acre. On the other hand, there are instances of salt destroying vegetation, in amounts varying from 772 lbs. to one and a half tons. In these latter instances, however, the salt was applied near the seed sowing. In these cases, also, it is recorded that the blighting effects of salt passed off completely in three or four months, leaving the land prolific and refreshed. All these experiments refer to refuse salt. If pure sodium chloride is used, a less quantity by 20 per cent. will suffice. In Falk's Pamphlet will be found the results of a number of experiments with salt on different crops, wheat, rye, barley, oats, beans, flax, hops, potatoes, turnips, carrots, mangold, grass, clover, etc., showing the proper amounts to use with each crop. He also gives a table of the same kind : but it is difficult to lay down laws on a subject complicated by so many considerations. Something must be left to individual local knowledge, and judgment; and to cautious preliminary tests to establish the exact amount of salt required by a given soil and by a given crop. In a general way, in the absence of special information, half a ton to the acre of suitable land will be a proper amount of salt to use. Mr. Fenn, of Cheshire, (*Rees' Cyclopædia, Salt,*) says, that his experiments show that a man sowing with a feed hopper, common stride, and

full hand, twice over the same ground, sows from ten to 12 bushels of salt per acre, 560 to 772 lbs. This may be of use to those who do not care to make the exact measurements required for experimental accuracy.

Mr. Lawrence Biggar, (*Agricultural Gazette*, 4th Dec. 1847,) notices a failure of salt manure due to excess quantity. He states that a prejudice existed amongst the farmers of his neighbourhood against salt, since one of them manured an acre of potatoes with three tons of salt with the effect of destroying his whole crop! This experiment, and the resulting scare, illustrate the growth of prejudice against salt. Insufficiency of salt, the opposite extreme, is an occasional cause of failure, as we see from certain recorded cases in *Johnson's Essay*. He states that land has been manured with 3 or 4 bushels of salt to the acre with negative results.

Still more disappointing has been the result of applying salt manure too often. It is the general opinion that the effect of salt upon the soil lasts from four to ten years. This is a different thing from saying that the salt itself continues in the soil. It should not be applied oftener than every seven years probably.

Nor should salt, or salt solutions, be deluged over young growing crops in too concentrated a form. That is, the salt should be ground, and not large and lumpy; and as has been already noticed, the solution cannot safely exceed in strength one part in 70, or 2 ounces to the gallon. As regards putting salt in the wrong place, there would seem to be little scope for error, yet Johnson, in the Essay above quoted, gives an instance of a man who dibbled in salt with his seed! The result of this remarkable experiment was that the seed did not germinate. It probably came under the influence of the antiseptic action of salt and was preserved from change

of any kind. The time of application is a matter of the first importance as regards the benefit of salt manuring. Salt requires time to undergo those changes which result in the production of fertilising salts. It requires time to prepare a solution of the silicates and earthy phosphates; and to lay up a store of ammonium chloride: hence it should be applied before these chemical foods are absolutely wanted. Moreover its immediate effect upon plants is very stimulating in quantities of half a ton to the acre, so that it is almost hazardous to use it with young growing crops.

The best time to apply the salt would seem to be about three or four months before the seed is sown. If after rain, so much the better. The salt then can exercise no injurious influence on seeds or growing vegetation; and before the seed is sown, it will have time to undergo a partial decomposition. It will retain moisture in the soil; destroy weeds and vermin; yield soda salts; render the silicates and phosphates of the soil, soluble; and there will be enough left to stimulate vegetation, and to protect the plants from parasitic attacks when the seed is sown. Salt has been sown at all stages of cultivation, and with benefit. But its application to *growing plants*, if desirable, must be surrounded with such safe guards as its blighting action suggests. We now come to the experiments of Mr. Lawes, of Rothamstead, Hertfordshire, made in 1864, and published in the *Royal Agricultural Society Gazette*, after having been the subject of a discussion at a meeting of the Society. These are the experiments chiefly relied upon by those who depreciate the value of salt as a manure. Mr. Lawes put down 4 cwt. of salt per acre, on selected sites, *in addition to other manures*. He continued this for *three years* in succession, and at the end of that time found that the land so treated did not differ in point of crop, or weight of grain, from ad-

jacent land similarly manured but without the salt. These negative results are pointed to as seriously damaging the reputation of salt manures. However Mr. Lawes experiments were, in some respects, faulty. It is sufficient to observe that his land was a *heavy loam, resting on yellow clay;* soil, to which salt manures are not applicable; and that he overshot the mark in applying salt three years in succession. The general opinion elicited from the Members of the Society, present at the reading of his paper, was in favour of salt. Experiments of this kind very generally fail in giving information as to the weather; yet temperature rain, and sunshine, are very important factors influencing the crop—independently of salt—which cannot be overlooked. The drainage of the land also influences the result of salt manures. Some few other experiments debiting salt with failure as a fertiliser, are on record in *Rees' Cyclopædia* and *Johnson's Essay on Salt;* but they are vitiated by one or other of the wrong methods of applying salt already noticed. Such failures are inevitable in the early history of all experimental essays with powerful manures. Indeed it is to their results that we owe the knowledge which we now possess of the value of salt, and the right way of using it. The failures noted in the above mentioned works bear a very small proportion to the successes; and all those who have written upon the subject, have written, apparently, strongly under the impression that salt is a valuable manure. Johnson's Essay which is a written advocacy of salt, passed in eighteen years, 1830 to 1848, through more than 20 editions.

Finally, in this connection, we must notice a pamphlet of M. Milne Edwards, which is quoted against the value of salt manures.

M. Milne Edwards wrote a report in 1850 on the results

of a French Commission which came to England to enquire into the effects of salt on corn. There was question at that time of restoring the old tax on salt, in France; and *the report was written in favor of that idea, and was published at the expense of the French Government.* It is wanting in judicial character; and is another illustration of the way in which the scientific question is prejudiced by the relation of agricultural salt to revenue matters. The opponents of the salt tax overdo the value of agricultural salt. Government servants, on the contrary, who write in favor of the tax, depreciate its manurial powers; and between them, salt gets a bad reputation.

To recapitulate briefly the rules which have been found by experience to govern the best results in the use of salt as a fertiliser. It may be said that salt is advantageous to light, sandy, or silicious soils; to light loams with much humus; to light marly soils; and to dolomitic soil; there is also some evidence to show that it is of use to dry peaty lands; but it is uncalled for on heavy wet or clayey soils. As regards time, it gives the best results when applied about three months before sowing time. It should be used in dry weather; but in damp soil. Of course if put down on well drained land, just before heavy rain, much of it will wash away. It is also not advisable to use it when the tender green shoots of the crop are just beginning to grow up. The best quantity to use, seems to be about half a ton an acre. Refuse salt, finely ground, is the ordinary kind of salt used. If pure salt should be used, a less quantity by 20 per cent. will suffice. The salt may be scattered broad-cast over the land or ploughed in; the latter is preferable.

Another way of using salt in agriculture remains to be noticed; that is, in ordinary farm yard manure. This

does not interfere with the uses of salt as a special fertiliser already detailed, and may be employed simultaneously, if the rules as to quantity are observed. Farmers appreciate the use of salt in this way. It is commonly added to dung heaps in Cheshire; and in fact wherever it is easily obtained. On the sea coast, farmers often water their dung heaps with salt water. In Brittany this is a usual practice. Sea weed manures point also to the advantages of salt. The late Mr. Mechi, and other scientific and practical farmers, strongly recommend it.

There are some special advantages in employing salt in manure. The salt prevents the too rapid decomposition of the manure and the loss of its volatile constituents, especially ammonia. It appears to cause the formation of ammonium chloride, with the necessary resulting liberation of soda, both valuable fertilisers. It kills the parasitic germs which find a suitable nidus in the dung heap, and which when applied to seeds and growing plants, develope at their expense. It has a hygienic value, also, as it preserves the farm yard atmosphere from the effluvia of decomposition. By its moisture-holding property, it prevents much of the loss of the valuable salts held in solution in the fluids of the manure, which otherwise drain away. It should be scattered over the layers of manure, as they are added to the dung heap.

Another way of using salt is to decompose it before applying it to the land. It is not salt itself that acts in this case, but its derivatives. The experiments of Guyton and Carney show that two parts of lime and one part of salt, mixed in a dry state and kept covered for three months, preferably with sods, decompose into calcium chloride and sodium carbonate. Earth seems to have a katalytic action in hastening the decomposition. This

gives some clue to the length of time salt takes to undergo a double decomposition in the soil; but the circumstances being less favorable in ordinary agricultural operations, a portion of the salt remains undecomposed for a much longer time. Johnson, who made some experiments with it, strongly recommends the use of this compost; and many practical farmers prefer it to the naked use of salt. I have often seen the natives in India clearing out their salt beds, and spreading the spoil over their rice fields, in marly localities. They have found by experience the benefit of the resulting chemical changes in the soil. It is also noticed that abandoned salt pans, in marly localities, soon form luxurious rice fields.

Mr. Manley spoke highly of the combination of salt and marl as a manure, in his evidence before the Committee of the House of Commons in 1818. The Minutes of evidence of this Committee, record much valuable information on the subject of salt in agriculture. A mixture of salt and soot is also highly spoken of as a fertiliser. Soot is said to enhance the power which salt has of absorbing moisture from the atmosphere.

Before leaving this branch of the subject, the use of salt in arboriculture, at least as far as fruit trees are concerned, requires a passing notice. It appears from numerous experiments that salt is beneficial to all kinds of fruit trees, when used with due care and attention. Even the cherry tree, of which the reverse is stated in the first edition of this work, owing to a recorded instance of a number of cherry trees having died in consequence of being flooded with sea water, is benefited by it. In the recorded instance, other causes were doubtless at work to injure the trees, but were overlooked. At any rate the negative evidence afforded by this single instance will not stand against the posi-

tive results obtained by Johnson and others. Johnson particularly notices a sickly cherry tree of his own which was quite recovered by the liberal use of salt. The flavour of the peach is said to be improved by salt. In Central India it is thought that fish manure, which is there a mass of very salt fish, is the best for vines. In cider orchards, a few pounds of salt laid round the tree, in a trench, a few feet from the stem, is found to improve the apples. The Berlin Horticultural Society have found that by the use of salt, they get juicier fruit. They loosen the earth about the roots and strew a thin layer of salt round the tree. Dr. H. C. Geubel states that the Persians never transplant their fruit trees without using salt. It is much used for rubbing on the stem of fruit trees to prevent the growth of moss. This may be a useful hint to coffee planters, whose trees suffer much from moss.

Apropos of trees.—The following extracts deserve a place amongst the curiosities of salt literature. The Abbé Molina, in his *History of Chili*, mentions a species of basil, which he calls *sogmum salinam*, which, though it grows sixty miles from the sea, is covered every morning with saline globules, so that each plant furnishes half an ounce of salt daily. In Mr. Vansittart's *Translation of Mahomed Cozim's Assam* there occurs : "Salt is a very precious and scarce commodity ; the better sort in common use is extracted from the plantain tree." The plantain, it is known, contains a little salt. E. A. Floyer (Unexplored Baluchistan) mentionss a *reaumuria*, called after him, which has the power of condensing on its leaves large crystals of salt, which if removed are reproduced again.

We now come to the use of salt for live stock, a distinct branch of the use of salt in agriculture. The advantages of salt to cattle have been known from the very earliest times : indeed there is every reason to believe that man himself has been educated in its use by observations made on cattle. Wild animals of the herbivorous tribes are impelled by instinct to make long journeys in quest of salt.

The American pioneers found broad beaten tracks leading through the forests to the salt springs, or salt licks, as they are termed locally. These forest highways were formed by the tramp of herds of animals, pressing forward to lick the salt mud, which formed around the salt springs. As late as 1798. Daniel Boom settled at the Great Buffalo lick, Kanawha County, West Virgina, to shoot bison and elk. References to the use of salt by cattle are found in the Bible, and in many of the classic authors. *Pallodius*, who wrote about the year 350 A.D. recommends salt for sheep. *Cato* (*Owen's Translation*, pp. 88, 105,) recommends a solution of salt to be rubbed on sheep as a preservative against ticks; he also notices its action in improving hay. *Virgil* (*Georgics*, Lib. 3, v. 394,) bears testimony to the advantage of giving salt to cattle. Conrad of Heresbach, a German author, *On Husbandry*, translated by Googe in 1570, recommends the use of salt for cattle. He says also, "Constantine out of Didimius affirmed that the scabs of sheep are healed by washing them with brine. Pliny, the naturalist, says, (*book* 21, *c.* 7,) "Herds of cattle being covetous of salt pasture, give a great deal more milk and the same is much more agreeable in the making of cheese."

Gregory the Great, in a metaphor, addressed to the Clergy, alludes to the practice of giving salt to sheep. It is worth noting that it is the need of salt for cattle which had much to do with the abolition of the salt laws in England.

Many pamphlets were published in the beginning of this century on the use of salt in agriculture. An Act of Parliament was passed in 1816, giving farmers power to use *rock salt* for cattle, on payment of a duty of £10 a ton, and giving bond for the remainder. On the motion of John Calcraft, M. P., Rochester, a Committee was appointed to inquire into the subject. On its recommendation the use

of rock salt was allowed for cattle, on payment of a duty of £5 a ton. In the Session of 1819, another Bill was passed by which farmers obtained refuse salt for manure, free from duty and bond, on condition of its being mixed with one-fourth part of ashes or soot. In 1824 the duty was removed altogether.

M. Roustan states that cattle deprived of salt, in Columbia, lost their fecundity: and *Phipson (Essay)* says our own climate furnishes us with similar examples. It is stated by Mr. Lambert, (*Annual Review*, 1804, p. 767,) that the natives of India formerly tamed wild cattle by making up balls of cotton and strong salt mud, which they left on the grazing ground. The cattle grew so fond of these balls that they would not leave as long as the supply was kept up.

The wild goat (*Izard*) hunters of the Pyrenees, make use of salt in their shooting expeditions to get within rifle shot of their game. They take a bag of salt with them up the mountains and salt a good spread of grass, in a region known to be frequented by the "*Izard*;" they then retire and make a wide circuit, coming up to leeward of the salted grass the next day, when they are generally rewarded with a shot. An experienced Pyreneean sportsman told me that the game find the salted grass very quickly and repair to it in numbers. It is believed, locally, that the salt melts in the night and that the game scent it with the morning dews!

Liebig remarks on this subject, (*Researches on the Chemistry of food*, p. 110); "An animal feeding on plants which contain phosphates of other bases, along with some compound of soda or sodium, produces in its body the phosphate of soda indispensable to the formation of its blood; but an animal living inland obtains in the seeds, herbs

roots, and tubers, which it consumes, only salts of potash, the chief inorganic constituent of its flesh, but no phosplate of soda which is a compound never absent in its blood. Whence, therefore, does it obtain the phosphate of soda? It is obvious that phosphate of potash is decomposed when in contact with sodium chloride, part of the potash combining with the chlorine, while the sodium replaces it in the phosphate; phosphate of soda being produced."

The gastric juice of sheep and cattle contains a larger amount of salt than that of men; sheep have 4·36 parts per mille, as against 1·46 in adult men. Cattle fed on bulbs, seeds, and the like, have less need of salt than cattle fed on straw and grass; but the latter want it much, since there is none in their ordinary food.

Some slight difference of opinion has existed as to the proper amount of salt to give cattle, to develope them to the utmost. The Patriotic Agricultural Society of Bohemia has made experiments with milch cows showing that with an allowance of two ounces of salt daily, they produce the most milk. The experiments of Bousingault, however, seem to prove that more is required, as he got negative results from the use of one or two ounces daily. (*Anls de Chimie*, 1847-48-49.) There is no question whatever as to the advantages of salt for cattle, etc. The experiments of Bousingault and Dailly, in France, and of various Agricultural Societies, Bohemia, Silesia, etc., and of numerous farmers, place this beyond all doubt. The experiments of the Agricultural Society of Silesia prove conclusively that cattle and sheep gain in weight, and the latter improve in wool and weight of wool, on a salt diet. Agriculturists of great experience, who have given attention to this matter for years, are stated by Johnson to have come to the conclusion that salt should be allowed to live stock in the following proportions. Horses, 4

ounces; cows, 4 ounces; oxen, 4 ounces; yearlings 2 ounces calves, 1 ounce; sheep, ¼ ounce; each, per day. They testify to its remarkable virtues in keeping cattle sound, and of curing them when diseased. In some parts of Germany, oxen receive 5 ounces of salt daily, and as much as 10 when fattening for market. The Swiss give nearly as much. (*Phipson's Essay.*) At the present day the general conclusion is that salt should be given without stint. Rock salt, left in some convenient place, where the cattle can have free access to it, is the best method of using farm yard salt. Animals, it is found by experience, will take as much as they require, and no more; and their own instincts and appetite for salt is the best test of the amount that is good for them.

Poultry, geese, ducks, and pigeons, should have a little salt in the food.

An instance of cattle, "salt hunger" and its results in India, is worthy of special attention. Some Indian cattle, especially *hill cattle,* are in the frequent habit of eating human and dogs' excrement by the way side. At one time I marvelled very much at this abnormal appetite; but subsequently finding that such cattle were depastured on poor grass—*without any salt whatever either in their natural food, or in the crude state,* I ceased to wonder, for these excrements happen to contain an appreciable amount of salt, and are often rich in it. The consequences of this habit are most disastrous. Such excrements often contain the germs or seeds of parasitic animals, (tape worms) which find within the cow's body, suitable conditions for their development. Working their way from the intestinal canal into the tissues of the cow, these little echinococci, as they are termed, develope into hydatids, or living water cyts, which grow rapidly. To all intents and purposes an hydatid is a bladder of water which developes in muscle lung, liver, brain, or heart, as the case may be: and which

gradually extinguishes life, impeding and arresting some vital function by its pressure effects. I have assisted at numerous *post mortems* on hill cattle, cut off in the flower of their youth, and invariably the fatal sack of fluid has been found, generally in the lung. I have also known herds of cattle which were gradually perishing from this cause, saved by a liberal use of salt. Not that salt is in any sense a remedy; but it is a prophilactic, or preventative of the disease. No greater economy can be practised by the Indian farmer, especially by coffee and tea planters, who keep herds of cattle for manure, than to give salt liberally—notwithstanding that its price is excessively high, as regards agriculture. Horses also require salt; not quite so much as cattle, as they are fed on grains which contain a little; but still they need to have that little supplemented. They relish their food better and eat more, have better health, have a finer coat, and work better, if they get salt regularly. As an instance of the equine craving for salt, Dr. Paris, (*Pharmacologia,*) quotes the Agent of the Real del Monte Silver Mines, in Mexico, to the effect, that the ore of the mine, silver sulphide, is heaped in masses with mercury, iron pyrites, and common salt, in the course of extraction: and that mules, on the works, lick these heaps to that extent, that though uninjured in life, it is not unusual to find considerable masses of silver in their stomachs after death. A remarkable note on the salt hunger of mules, will be found in the appendix.

It is a common practice with horse owners in India to mix a good handful of ground salt with the horses food, morning and evening, and I can testify, from experience, that it keeps the horse in good condition. Salt is a cure for bot in the horse, and is otherwise used in veterinary practice, as has been noticed in the medical chapter.

In the Memoirs of the Royal Academy of Science, Paris, it is related, that at a place called Crau, in Provence, numerous flocks of sheep, with the assistance of a liberal supply of salt, are reared on a sterile tract which contains hardly a tree or a bush, and which is so stony and barren, that in dry seasons, the sheep are obliged to turn up the stones to get at blades of grass. The wool of these sheep is said to be the finest and the dearest in France.

In Spain, the celebrated Merino sheep have one ton o salt annually to each 100 head. In the departments of th Seine and Loire, the most agricultural of France, sheep ge salt in their water.

Uberacker, a German agriculturalist, wishing to obtain experimental proof of the value of salt for his sheep, herded on a low damp pasture, stopped the usual allowance of salt to ten of them. Five of the ten sheep died that year from cachexy and worms; whereas, of the rest of his flock, 450 head, he lost but four sheep. Next year he repeated the experiment with ten other sheep, and lost seven of them; only five sheep dying in the rest of the herd. A third year he tried again, depriving sixteen sheep of salt this time, and lost them all. They died of cachexy, worms, and pneumonia. The third year was very wet. (*Phipsons' Essay.*)

Sheep depastured on salt marshes in England are not known to suffer from the rot, or liver fluke. Professor Simmonds, in his reports on the sheep rot, frankly admits that there is no other specific for the prevention of that disease, save salt, and salt alone.

In the years 1879 and 1880, the rot carried off about three millions of sheep in England and Wales; upon this the Royal Agricultural Society appointed a Commission to investigate the subject, and the Commission reported that the regular use of common salt was a preventative of that disease.

Cats and dogs are shy of salt *per se :* though they will eat salt meat, or fish, or food seasoned with salt. Being carnivorous, they are used to salt in their food and should have some added if their food is boiled. Sir J. Ashley, of Milton Constable, in Norfolk, is said by Johnson, to have given a table-spoonful of salt to each of his fat hounds, weekly ; and it kept them in good health and warded off the distemper. Pigeons are very fond of salt, and the whole tribe of farm yard poultry are benefited by it. Bees require a little salt occasionally. If a solution of salt, 4 or 5 ounces to the gallon, be left in their neighbourhood, they will, themselves, take as much as they require.

In the process of *ensilage,* or preservation of hay and green crops in pits or silos, in the United States, salt, according to the "Report of the Commissioners of Agriculture of the United States of America for the year 1875," is used with great advantage. It is used also both in America and in Europe, in preserving hay in the ordinary way, by stacking in the open air, in the proportion of 14 lbs. of salt to the ton of hay.

Youatt states that salting hay, discolours it. He however highly approves of it as fodder for horses. It is well known that horses and cows prefer an inferior quality of hay, moistened with brine, to a superior quality which has not been salted. Salt keeps the hay from moulding. Damaged hay can be preserved by its use. Lord Somerville (*Facts and Observations on the use of Sheep Wool,* p. 104,) recommends 25 lbs. of salt to the ton of hay. It is sprinkled on each layer and screened if thick and lumpy. A Commission appointed by the French Government recommends that hay be salted at the rate of 4 to 10 lbs. per ton. (*Moniteur, No.* 1,386.)

Barilla.—The soda got from the ashes of marine plants is called barilla. Certain plants which grow wild in salt marshes, or by the

sea shore, where there is a supply of sodium chloride, assimilate and convert it into soda, yielding the latter on calcination. Such are the *salsola or salicor, kali, salsola sativa, salicornia herbacea, &c.*, of the genera *Chenapodium* and *Salsola.* These were cultivated largely, formerly, in Spain and France; large tracts of country, by the sea, being devoted to this purpose. In the South of France *salicor* and wheat were grown together always. In wet seasons, the wheat ripened, and the salicor died; but in dry seasons, the salicor prospered, and the wheat died; so that there was certain to be a crop of some sort. Large quantities of this barilla were once imported into England, for the use of soap, and glass manufactories, at prices ranging from £30 to £60 a ton. In 1817 the import of barilla amounted to 10,360 tons, and the duty to £87,883. The Leblanc process of making soda, directly from common salt, has superseded the use of barilla in England; but there are countries, less fortunately circumstanced, that might still perhaps find a profitable resource in its manufacture. Kelp is still made on the West Coast of Ireland.

CHAPTER IX.

THEORY OF BAY SALT MANUFACTURE.

The manufacture of bay salt, by solar evaporation, does not appear to have flourished until comparatively recent times. Schleiden says that Ancus Martins was the first to make it. In the localities in which civilized man is believed to have earliest taken root, Asia Minor, and Central India, and Northern Africa, there was no need to make salt, since natural salt existed in abundance. And as regards less fortunate places, and less civilized people, they are generally credited with conforming to a diet which rendered them, like carnivorous animals, independent of salt. The earliest records of salt manufacture, relate to the boiling of salt. This method of getting it was practised in China from immemorial times, and is still in active operation in the Province—Young, Ḥian and Wei Yuan Hian where salt is associated with mineral oil. Columella instructs us how to procure salt by boiling. Pliny, the elder, A. D. 70, mentions that salt was obtained from the sea by pouring sea water upon burning embers. The product of this early form of manufacture is believed to have been so dirty as to have given rise to the French, *sal*; Irish, *salah*; Hindustani, *sala*, etc., dirty. This would scarcely encourage its manufacture. Salt formed spontaneously from the sea, in the swampy tracts of low lying shores, was also disliked. Often complex in its nature and injurious in its action, a prejudice grew against it. The Celts appear to have been the first to develope bay salt

manufacture. The Haloren, a tribe of Celts, were named from *Hal*, salt. Hayling Island, near Portsmouth, the oldest site of bay salt manufacture, in England, is clearly, from the name, of Celtic origin. The Danish Invaders of England, in the 7th century, spread the knowledge of bay salt manufacture, and introduced the term *wick* or *wich*, which has since distinguished salt villages. All this will be found, in detail, in the Historical chapter. At the time of the Conquest, salt manufacture was a widespread, and a very paying industry in England. For a long time, however, the salt made in England was of the poorest quality. All the finer sorts were imported from Venice and Holland. About the year 1440, Henry VI. of England, invited John of Sheidame, with sixty followers, from Zealand, to England, to teach the art of making salt. Some improvements were doubtless affected, but for the next two centuries, English salt remained inferior to that of Holland, as is noticed by writers of the period. In its early days the Royal Society gave much attention to this subject. W. Jackson, M.D., published a paper in the *Philosophical Transactions* for 1669, on the method of making salt. This was followed by another paper on the same subject, in the year 1678, by Thos. Rastell, M.D. Then came Brownrigg's book, the first attempt at systematizing this subject in the English language.—"The Art of making common salt." William Brownrigg, M.D., F.R.S., London, 1748. In these we may trace the early struggles of the art of salt manufacture. Thirty-seven years later, Archibold Cochrane, Earl of Dundonald, a Scotch salt work proprietor, published a work entitled "The Present State of the Manufacture of Salt explained." It throws no fresh light on the subject, and is chiefly devoted to the recommendation of a hearth tax, instead of the salt tax, which pressed upon his property. All these works are

in the British Museum. It is only within the last few years that the researches of Chemists have raised salt manufacture to the level of a scientific art. We are indebted chiefly to the French Chemists, Balard, Dumas, and Berthier, for these advances. France is now, owing to its advantageous situation on the Mediterranean Sea board, the encouragement of its Government, and the enterprise of its citizens, *facile princeps* in Europe, in the matter of. bay salt culture.

To enable the reader to understand the technicalities of salt manufacture, it must be considered under two heads, theoretical and practical. The theoretical portion will be taken first. In connection with the first part, Beaumé's hydrometer will be noticed—a little instrument which plays a most important part in salt manufacture.

Beaumé's Hydrometer.—This instrument is indispensable to the salt manufacturer. It tells him how the evaporation of his brine is progressing, and what changes are taking place in it. It is of very simple construction. It consists of a weighted glass bulb with a projecting graduated stem, which floats erect in solutions heavier than water, at different levels according to the density of the solution, showing by the graduation on its stem the density of the fluid. There is another Beaumé's hydrometer for alcohols and fluids lighter than water, which is only mentioned here, to prevent its being mistaken for that used in salt manufacture. The latter is graduated as follows. The point to which the stem sinks in distilled water at 60° Fr. is marked 0°; then 15 parts of common salt are dissolved in 85 parts of water, and the point to which the hydrometer sinks at the same temperature is marked 15°; the interval between 0° and 15° is then divided into 15 equal degrees, and the scale is further continued to 40 by means of similar equal parts

0° Beaumé is therefore equal to distilled water, and 15° B. to 15 per cent. of salt is a simple solution. In a complex solution, other salts influence the density, and consequently the reading of the hydrometer; but as regards sea water, the value of each degree, as far as salt is concerned, is known by experience. Solids in suspension make no difference. The hydrometer reads much lower in muddy river water, than in clear sea brine.

These hydrometers can be used all over the world; practically speaking, differences of temperature do not affect their accuracy in the least. For those, however, who care to trace the subject further, the following determinations of the variations in volume of salt solutions at different temperatures by Kremers, (*Jahresb*, 1857, p. 68) is here given.

Volumes of Aqueous Chloride of Sodium at different temperatures (vol. at 19·5° C. = 1.)

Quantity of salt in 100 pts. water.	4·7	10·0	15·4	20·5	26·3	31·4
	Vol.	Vol.	Vol.	Vol.	Vol.	Vol.
0° C.	0·99639	0·99475	0·99371	...	...	...
10	0·99783	0·99715	0·99674	0·99644	0·99620	0·99604
19·5	1·00000	1·00000	1·00000	1·00000	1·00000	1·00000
30	1·00327	1·00381	1·00410	1·00435	1·00456	1·00468
40	1·00710	1·00790	1·00840	1·00878	1·00910	1·00928
50	1·00150	1·01246	1·01309	1·01353	1·01391	1·01412
60	1·01646	1·01748	1·01817	1·01860	1·01898	1·01919
70	1·02201	1·02303	1·02364	1·02400	1·02431	1·02454
80	1·02809	1·02889	1·02945	1·02971	1·02993	1·03006
90	1·03466	1·03524	1·03560	1·03576	1·03581	1·03591
100	1·04179	1·04209	1·04217	1·04214	1·04211	1·04190

From a series of experiments and observations on the expansion of sea water by heat, Messrs. T. E. Thorpe, Ph. D. and A. W. Rucker, M.A., have arrived at the following general formulæ. $V = \phi(t) + \psi(t) f(s)$. Giving the relation between the volume (V), the temperature (t), and specific gravity at 0°C (s) of any solution of the same composition as sea water, the specific gravity of which at 0°C lies between 1·020 and 1·033, the volume at the same temperature being taken as unity; in which expression

$$\phi(t) = 1 + \cdot00008097\,t + \cdot0000049036\,t^2 - \cdot000000012289\,t^3,$$
$$\psi(t) = -10^5\,(\cdot5509\,t - \cdot020198t^2 - \cdot00033276\,t^3) \quad \text{and}$$
$$f(s) = 11{\cdot}95 - 940\,(s - 1{\cdot}02).$$

In the original paper (an abstract of which is given in *Nature*, vol. 13, p. 237,) it is shown that if σ be the specific gravity at any temperature +, and of a solution the specific gravity of which at 0°C is S, $\frac{d\sigma}{ds}$ may without sensible error be assumed to be constant; whence by means of the above formula, the authors are able to give in a table, all the data necessary for calculating the specific gravity of sea water of any degree of salinity at any temperature between 0° and 36°C.

A table showing the specific gravities corresponding to each degree of Beaumé's hydrometer is furnished below, as it will be found practically useful; and degrees of Beaumé will be employed in denoting brine densities in the following pages. The author constructed this table with great care, employing for the purpose both the German hydrometer with the specific gravities marked on the stem, and separately weighing each sample of brine in the usual specific gravity bottle. The results were reduced to 60° Fr.

Table of actual Specific Gravities, corresponding to the Degrees of Beaumé Hydrometers.

Beaumé.	Specific Gravity.	Beaumé.	Specific Gravity.	Beaumé.	Specific Gravity.
0 ...	1,000	14 ...	1,110	28 ...	1,238
1 ...	1,010	15 ..	1,118	29 ...	1,249
2 ...	1,019	16 ...	1,128	30 ...	1,260
3 ...	1,026	17 ...	1,138	31 ...	1,271
4 ...	1,033	18 ...	1,148	32 ...	1,282
5 ...	1,040	19 ...	1,157	33 ...	1,293
6 ...	1,048	20 ...	1,167	34 ...	1,305
7 ...	1,055	21 ...	1,175	35 ...	1,317
8 ...	1,063	22 ...	1,182	36 ...	1,328
9 ...	1,070	23 ...	1,190	37 ...	1,340
10 ...	1,078	24 ...	1,199	38 ...	1,352
11 ...	1,086	25 ...	1,208	39 ...	1,364
12 ...	1,093	26 ...	1,217	40 ...	1,376
13 ...	1,102	27 ...	1,227	... ...	......

For convenience the word Beaumé is frequently denoted by the letter B in the following pages.

Impurities.—As a preliminary to the consideration of the subject of salt manufacture from the sea, it is necessary not only to be acquainted with the various salts it contains, but also to study their behaviour and mutual reactions in solutions of various degrees of concentration, at different temperatures; for, upon this depends the process of manufacture, which will be hereafter described in detail. Having already discussed the Qualitative and Quantitative annalysis of sea water, it may be said that as regards solar evaporation in the tropics, or evaporation by artificial heat of any kind, there are only three salts, besides sodium chloride, which require consideration, with reference to the practical work of manufacture of marine or bay salt. These salts are those the tests for which have been given in a previous Chapter, *viz.*, magnesium chloride, magnesium sulphate,

and calcium sulphate. The first, magnesium chloride, is ever present with sea salt. It exercises a most potent influence on its wastage, and is the cause of its hygroscopic manifestations. Magnesium chloride does not occur in the list of salts distinguishable from sodium chloride by outward form, (p. 47), though it crystallizes in a different system, for the reason that it is impossible to isolate it, or obtain it, as such, by the process of evaporation, naturally, or artificially, conducted. It holds its solvent water with such force, that the latter is decomposed at the close of evaporation, yielding up its oxygen to the magnesium, to form magnesium oxide, and its hydrogen to the chlorine, which is evolved as hydrochloric acid, as shown by the annexed formula. $MgCl_2 + H_2O = MgO + 2\ HCl$. Such is its attraction for moisture, that even the above decomposition does not take place below 212° F. The Indian sun, although the black bulb thermometer registers from 140° to 150° Fr., is unable to affect it; the abstraction of moisture from the sea air more than keeping pace with evaporation. So rapid is this abstraction that the author found it impossible to study the artificially prepared crystal, under a microscope, in Madras, in the month of July; it ran into a clear solution before there was time to adjust the instrument. Any one, who has had a felt hat dotted with sea spray, will have noticed beads of moisture forming upon it in damp weather. This is the deliquescence of magnesium chloride; and when we consider the amount of it, but ·3 per cent. at most, contained in the original minute drop of spray, it is easy to form an idea of the wastage likely to result from combining two such soluble salts as magnesium and sodium chloride, together. Besides its hygroscopic effects, magnesium chloride acts as an irritant on the mucous membranes of the body; and is credited, and probably rightly so, with the causation of irri-

table skin eruptions and bowel complaints. Hence, one of the most important points to which the attention of salt manufacture is directed, is to exclude it as much as possible from the out-turn of common salt.

Magnesium sulphate, or Epsom salt, is a well known purgative. This salt does not, under ordinary circumstances, enter into the composition of samples of table salt; nor is it difficult to avoid in the manufacture of such salt; but when it is stated that it is sometimes produced in such large quantities, by ignorant and unscientific methods of manufacture, as to necessitate the temporary closing of large and important salt works, it will be seen that it deserves more than a passing notice.

As regards calcium sulphate, it is of no interest viewed in relation to the purity of salt manufacture. It is contained in minute quantities in most sea salts, but it is under the circumstances a very harmless impurity. Its chief action in salt manufacture is to accumulate in the form of a thick crust, or cake, of gypsum, ($CaSO_4 + 2\ H_2O$), on the bottom of evaporating pans. It impedes evaporation in artificial works, and hinders the circulation of brine and the preparation of clay floors, in natural brine pans.

We must now consider how these salts are to be severally managed in salt culture, so as to admit of pure sodium chloride being obtained. This depends practically on their solubility, or the degree of concentration at which they form saturated solutions.

Solubility curves.—Any number of soluble salts, which do not mutually decompose each other, may exist coincidentally in a given bulk of water, if there be sufficient water to dissolve them all; but as we diminish the quantity of water, the salts will separate, the less soluble first and the others according to their degree, until a point is

tively, cannot retain any of it in solution. M. Berthier, a French Chemist, who devoted much attention to the study of this question, found that calcium sulphate is more soluble in brine of sp. gr. 1·033, than in ordinary sea water of sp. gr. 1·026; in fact, that it reaches its maximum of solubility at that degree. He found, in a Bavarian salt spring, that the solubility varied with density in the following curious manner:—

Degrees Beaumé.	Calcium sulphate dissolved.
0	0·0033
2	0·0043
5	0·00605
15	0·0043
27	0·000

It follows from this, that calcium sulphate does not separate from sea water until its density has been raised beyond 5° B., or sp. gr. 1·033.

Practically, calcium sulphate begins to separate from sea brine at 17° Beaumé, equal to sp. gr. 1·138; and at 25°B,= sp. gr. 1·208, hardly a trace of it remains. Here it is important to note that sea water, the ordinary density of which is 3° B, loses about five-sixths of its volume in evaporating to 17° B.

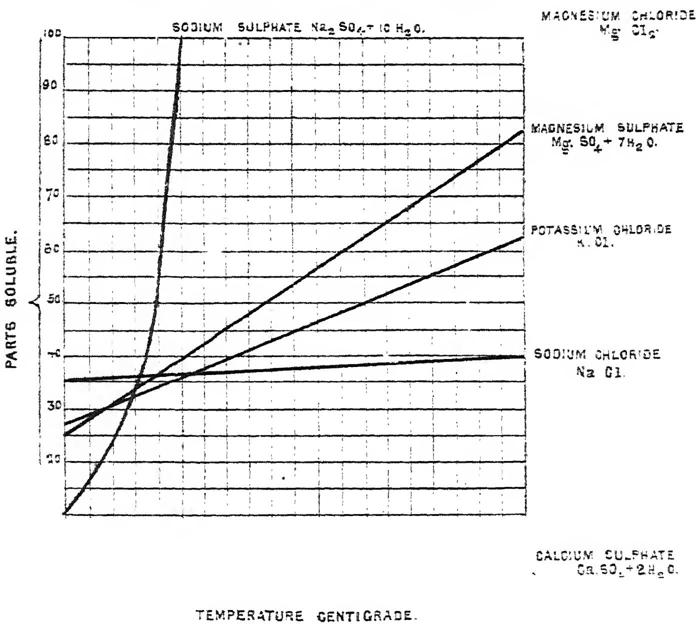
Sodium chloride is the next salt to separate. It begins to separate at 25° B. At this stage of evaporation, sea water is found to have been reduced to about one-tenth of its original bulk. The amount of common salt it contains, which originally stood at 2·8 per cent. has, therefore, been raised to 28 per cent. As water at ordinary temperatures is capable of dissolving about 37 per cent. of common salt it should not separate so soon; but it is forced to crystallize out, by the other salts in the brine, which have a superior attraction for water. This forcing action is an important one to keep in view in salt manufacture. It tells

with greater energy as the evaporation proceeds. At first sodium chloride crystallizes out slowly, well formed, and in a perfectly pure state. But as the process proceeds, and the other salts feel, as it were, the loss of the aqueous vapour carried off by evaporation, salt is forced out more rapidly, and its crystallization becomes very imperfect. As 32° B., the point of saturation of magnesium sulphate, is approached, the latter, in its turn, is similarly acted upon by the residual salts, and is forced out, and sodium chloride can no longer be obtained pure. At this point, salt manufacture always ceases; but it is not safe to push its formation so far, except with first charges of brine, evaporated in perfectly clean vessels; otherwise a sensible amount of magnesium sulphate will be gathered with the salt crop. The author's experiments tend to show that at 30° Beaumé, not more than 3 per cent. of the original sea water remains, and consequently not more than ·9 parts of the original 28 parts of salt it contained; and as this is precipitated hurriedly, from a strong magnesium brine, probably with some magnesium sulphate, it hardly pays to get it. Twenty-seven parts of salt, per thousand of sea water, is the most that can be got out profitably.

Mother-liquor.—The manufacture of common salt ceasing when the brine marks 30°B, the concentrated residual brine, from which it has separated, is called at this point *Mother-liquor*, (the Germans call it *bitterns*.) If the evaporation is continued, from 30° to 34° Beaumé, sodium chloride and magnesium sulphate are deposited together, the latter in an increasing ratio; and finally the "bitterns" becomes a saturated solution of magnesium chloride, calcium and potassium chlorides, and the iodides and bromides of the alkalies, when present. This mixture cannot be decomposed by solar evaporation.

reached—complete saturation—when those remaining are thrown down together. The following diagram of the curves of solubility of the different salts concerned, will illustrate and explain the further remarks on this subject. The curves have been roughly drawn as straight lines. The line of solubility of magnesium chloride, placed above the diagram, is relatively, if not absolutely, correct. It is placed up, out of the way, as it is the most soluble of the salts noticed, and does not change the position of its curve with reference to the other curves, at any temperature or any period of manufacture; though in point of fact, it is more soluble in warm than in cold water, and is decomposed at a little above 212° F.

DIAGRAM OF SOLUBILITY IN 100 PARTS OF WATER.



It will be observed that the curve of solubility of sodium sulphate is extremely sensitive to temperature, and this is a matter of some practical interest. At low temperatures, near the freezing point, magnesium sulphate and sodium chloride, in strong solutions, break up, and their molecules reform as sodium sulphate and magnesium chloride. An example of the re-grouping of these elements, at the Sambhur Lake, is mentioned at page 44. As the temperature rises, the new salts undergo a second double decomposition, and reform into magnesium sulphâte and sodium chloride; and this conservative or renovating action, as regards common salt, is complete at about 60° Fr. It is important, therefore, in salt manufacture, to gather sea salt at or above that temperature. It will be seen from the diagram that above the temperature of 25° C., or 77° Fr., all the other salts, except calcium sulphate, are more soluble than common salt; so that the latter must crystallize first, out of solutions evaporated beyond that temperature.

On the other hand, calcium sulphate is so little soluble, that it separates long before sodium chloride approaches saturation. Its curve is peculiar. At the freezing point, 0°C, 100 parts of water dissolve 0·205 parts of calcium sulphate; at 35° C, 0·254 parts; and at 100° C 0·217 parts. Its solubility increases from 0° to 35° C, the temperature of maximum solubility, and from 35° C to 100° C, its solubility decreases again, but more gradually.

The practical effects of these curves of solubility are shown in the evaporation of sea water as follows. Calcium sulphate is the first salt to separate. It is not contained in sea water in the same proportion that it would be in fresh water, as its solubility diminishes in the presence of sodium and magnesium chlorides; water, for example, containing 22·1 and 23·8 per cent. of these salts, respec-

springs, impure rock salt formations, inland lakes, and from saline earths. Sometimes two or more of these sources are combined together for the manufacture of salt; as brine springs and sea water; brine springs and rock salt; sea water and saline earths, etc. Sometimes it is manufactured entirely by artificial heat; sometimes entirely by solar evaporation; and sometimes by a combination of both. As regards the choice of these different methods, everything depends upon the circumstances of each case, the strength of the brine, the power of the sun, the cheapness of fuel, labour, etc. Examples of each, illustrating these points, will be given later on.

In the first instance, salt manufacture from sea water by solar evaporation, or *bay salt culture,* will be examined. This subject requires a chapter on the selection of sites; and one on the method of constructing and working salt gardens, or salterns, (called *salines* in France.)

CHAPTER X.

SALT GARDEN SITES.

The manufacture of salt from sea water, by solar evaporation, requires to be conducted in localities possessing natural advantages of soil, level, climate, drainage, brine supply, etc., etc. Before proceeding further it will be necessary to take note briefly of these important factors in the process. However simple an affair it may appear to be to select an appropriate site for salt culture, the numerous failures that have been made, and the time and money that have been misspent, show, that want of knowledge of this subject exists.

To meet this want, I have ventured to throw into the form of rules for the guidance of the manufacturer the information on this subject which I have gained in the course of five years' practical experience of the work.

The site chosen should be close to the source of brine supply, the sea if possible; otherwise the mouth of an estuary. It should be about the level of the brine required; in no case much above that level; though it may be at a lower level with advantage. It should not present a dead level surface. If it have a uniform slope in any direction, it is good; if from the direction of the water, landwards, so much the better; but any gently undulating surface is

At 30° Beaumé the Mother-liquor contains in 100 parts
16·6 Magnesium chloride
4·6 Sodium do.
2·0 Magnesium sulphate.

In cold or temperate latitudes, at about this point, a series of double decompositions begin in the brine; caused by the action of cold on the curves of solubility before noticed. Regnault, drawing his information from M. Balard, who has studied this question, in a very special way at the Mediterranean salt works, says: "The concentration of the sea brine continued on the clay pans, furnishes during the day, by *evaporation*, almost pure sea salt; during the night by *cooling*, magnesium sulphate. These two deposits take place generally on the same pan; so that a very coherent saline stratum is obtained, composed of crystals of sea salt, cemented by magnesium sulphate. The magnesium sulphate being less soluble in water containing magnesium chloride than in pure water, the wealth of magnesium chloride in sea water, contributes greatly to this deposit of magnesium sulphate. If the temperature of the air falls quickly to 10° centigrade, the brine, if let on to an empty pan, would furnish a large amount of pure magnesium sulphate. As soon as the brine reaches a concentration of about 34° Beaumé, it begins to deposit potassium sulphate. This is not deposited pure, but in the state of a double sulphate of potassium and magnesium. $MgK_2(SO_4)_2 + 6H_2O$. At this stage, the brine almost ceases to deposit sodium chloride; but deposits the double sulphate almost exclusively, both by evaporation and by cooling. The coarse, double salt, collected in the pan, is easily obtained in a state of purity, by re-dissolving and re-crystallization. When the brine reaches a density of above 36° Beaumé, it deposits, especially on cooling, a new product, a double chloride

of potassium and magnesium. But the deliquescence of magnesium chloride, which is still present in large quantities, renders the evaporation difficult. It is better to carry out this process by means of artificial heat. And if care is taken not to use artificial heat until the brine has been exposed for some time to a low temperature, as + 2° or + 3° Centigrade, by which means it gets rid of all its magnesium sulphate, one can obtain almost the whole of the potassium in the state of a double chloride of magnesium and potassium. When the brine is evaporated to 40° Beaumé, it contains nothing but magnesium chloride, which is deposited in voluminous crystals at a temperature of about the freezing point. At low temperatures, commencing at about + 2° C., magnesium sulphate and sodium chloride break up and reform as sodium sulphate and magnesium chloride; the equation is $MgSO_4 + 2\,NaCl = MgCl_2 + Na_2\,SO_4$." This re-grouping of the elements of the bitterns is sometimes taken advantage of for the production of sodium sulphate. This subject will be recurred to later on, when there is question of dealing with the Mother-liquor practically.

The following table shows how the volume of sea water shrinks, in evaporating from 3° Beaumé to 34° B.

Density in degrees Beaumé.	Volume.	Volume found by M. Balard.
3°	1,000	......
7°	500	......
17°	180	......
25°	100	93
30°	25	20
31°	......	5
34°	......	3

Salt is manufactured, commercially, from sea water, brine

better than a flat. It stands to reason that an irregular surface of hills and hollows will not suit. The soil must be of an impermeable kind, though it need not be impermeable in the strict sense of the word. It should be as free as possible from vegetation, and the burrows of crabs or animals.

Brine supply.—In the chapter on sea water this subject has already received some attention. The sea itself is the best source of brine for salt manufacture, for the following reasons: it is a constant source; it contains a fixed percentage of sodium chloride; it is a comparatively pure source; it maintains a fixed mean level; it rises and falls at known intervals daily. In contrast with this, estuaries are inconstant as a source of brine supply; for example, they often silt up. The percentage of sodium chloride they contain is very variable, as it depends on the rainfall; sometimes they are filled with fresh water. Estuary brine varies in level from month to month; and its variations cannot always be foreseen. Some of these remarks, regarding estuaries, have exclusive reference to the tropics, where they are affected by the extremes of season, the dry and the wet, as well as by cyclones and lesser storms. There are estuaries in warm latitudes, which though weaker than the sea, are not open to all the objections noted, and which may consequently be drawn upon with advantage, in salt culture. Besides, as salt manufacture is limited to the dry summer months, the whole question turns on the usual state of the estuary during that period. Other conditions of the site selected may be, to a certain extent, overlooked, if the permanency of the brine supply, as to proximity, level, and strength, can be guaranteed. Most of the salt factories on the Coromandel Coast of India, derive their brine supply from estuaries. They are in consequence liable to many accidents.

Nevertheless these salt works are so far successful that they turn out a fair quality of salt, and keep the supply up to the demand. In practice the objections to estuaries as sites of salt manufacture are outweighed by their contingent advantages of soil, level, etc. The fact that sea salt has been, for many centuries, and still is, almost everywhere, manufactured in bays, is sufficient indication of the value of the practice. The name *bay salt* is an evidence of this. When bay salt works come to grief, it is generally through want of proper precautions.

The level of the site, as regards its brine supply, has a most important influence on the cost of salt manufacture. In fact, in natural salt works, the raising of brine is the chief element of expense. If brine could be flooded into salt works by natural forces, and made to flow automatically, the cost of salt manufacture would be diminished more than one-half. Most of the Mediterranean salt works are on a lower level than the sea, and are filled from it, by sluice gates, at the ordinary sea level. In India, all the salt pans are at a higher level than the sea, and are filled by artificial means. Salt works at a lower level than the sea, cannot be drained without pumps; and though this is a matter of comparatively small consequence on the dry Mediterranean Coast, it is not so in the tropics, where three or four inches of rain may fall at any time and flood the works. On the other hand, in all salt works it is necessary to provide means to carry off the "bitterns," and this can only be done by pumping in works which have no natural drainage outlet. But as the volume of brine required for salt manufacture, as compared with that of the bitterns to be removed, is as 1,000 to 10, it is much cheaper to pump out the bitterns and rainfall, than to pump in the brine. High level pans have another drawback, they suffer more from leakage

than low lying works. At, or below, the level of the sea, the soil is moist, and the sub-soil is saturated with brine, which tends greatly to diminish wastage by percolation from the works. At higher levels, no matter how good the soil, and how well prepared, there is always some surface drainage out of the works, and some natural percolation going on through the soil, but especially at weak points of embankments or canals, where the loss may be considerable.

Salt works, below the sea level, have to be protected from storm-waves, and spring-tides, by embankments; they must also be cut off from surrounding fresh water drainage, by canals and embankments. Practically, this is not so expensive an item as it may appear to be at first sight, for all salt gardens, at whatever level, require a good deal of canal cutting, and embanking, in their proper internal arrangements. External works of the kind may generally be made to a certain extent subservient to this end. Even high level pans must be cut off from drainage, if there be higher land around, as there generally is.

A level about a foot below the point reached by the sea at ordinary flood-tide, would appear to answer best for natural salt works. It affords facilities for obtaining a constant supply of pure sea water, and for irrigating the works at a very great economy of time, labour, and expense. It obviates loss from leakage, &c. In no case should a site be chosen for salt culture at a higher level than ten feet above the source of brine supply, owing to the cost of pumping.

On the Atlantic Coast of France, the salt gardens are *excavated.* In Brittany the surface of the soil seems to be about three feet *above* high tide level; but the ground is excavated some four feet, to allow the flood tide to enter the salt pans. The expense of this work must be consider-

able; but the people prefer it to pumping up the brine. It enables them to attend to other occupations during the day, leaving the sun and sea to carry on the manufacture of salt. The salt makers are mostly farm labourers. They visit the salt pans every two days, in the evening, after their farm work is over, to scrape up the salt, and spread out fresh brine to crystallize. Summer showers are generally allowed to evaporate in the pans, with the loss of a few days' work. The works could be drained, as the tide falls about twelve feet; but a network of supply canals would have to be undermined for this purpose, and as the brackish water, run out, would have to be replaced by fresh sea water, the game is not considered worth the candle.

Pumps.—Whether a high level or a low level site is chosen for salt manufacture, a good deal of pumping has to be done; and the expense of this work tells very considerably on the ultimate cost of the salt. It deserves, therefore, special consideration. No one should embark on salt manufacture who has not thoroughly understood and counted the cost of pumping. In natural salt works, the height to which brine has to be raised, seldom exceeds six feet. At almost all the Coromandel Coast-pans, it is less than this, ranging from two to five feet. The volume of water daily required for the use of the works is found in India by multiplying the superficial area of the whole salt garden by ·5 of an inch, as half an inch of water is removed from the surface daily, by leakage, drainage, and evaporation. About 1,808 cubic feet, or 21,264 gallons, of brine per acre, a day, will therefore have to be supplied to make up the deficiency. Salt gardens below sea level will not require so much, as they do not suffer so much from leakage and drainage. The areas of salterns vary very much, but no saltern should be much less than 100 acres in extent; and economic manu-

facture will best be conducted on a larger area. A saltern covering one hundred acres will require 2,126,400 gallons of brine a day in India; in cooler countries it will be less; but it will be wise to make provision for that amount, owing to the unknown quantity, leakage.

Steam.—Unquestionably where fuel is cheap, and a permanent supply is at command, steam machinery may be employed to raise the brine. In some respects steam is at a disadvantage, however, in salt works. In the salt air of the coast, iron rusts with great rapidity; fresh water for steam engines is not often procurable, and when it can be had, it is of a quality to prime the boilers constantly; and, finally, open air salt manufacture has but a short annual duration, not more than five or six months at most. The up-keep of idle steam gear is thus a great loss. The mistake has been made in India of supplying kindred works with steam machinery, at a place in which the natural fuel resources of the country were soon exhausted, and where coal was expensive and difficult to procure, either by sea or land, with the result of failure.

Tampons.—In many of the Mediterranean salines, steam, or mule tampons, are used for raising brine; and the French Engineers speak very highly of them. The tampon is not unlike the paddle-wheel of a steamer; it works in a case in the same way, and with about the same dip, but the case forms part of the wheel. Instead of having spokes and floats in straight lines, radiating from the axle, it has curved partitions, which with the sides of the case, form boxes. The broad mouth of the box dips into, and owing to its curve, takes up the brine and as the wheel turns round the brine falls back upon the axle, where an opening allows it to flow out, into a trough, which carries it away. The lift is not equal to the length of the radius of the circle, as a portion of the radius is under water, and the axle and openings occupy the centre. A wheel of about 12-feet diameter will raise brine from three to four feet. Tampons are not adapted for much higher lifts. A 12-ft. mule-wheel raises water 3·25 feet, at the rate of 7·101 cubic feet per hour. As this amounts to 265,434 gallons in the working day of six hours, it is a cheap method of raising brine.

Wind-mills.—At Hayling Island, near Portsmouth, water was pumped to the works by means of wind-mills. If wind pumps have been found to work well in the summer months, and hold their own

in practical and economic England, they may be expected to work at least as well on the salt swamps of the tropics, where the regular trade winds blow steadily throughout the salt season. On the other hand, wind-mills, even in the tropics, are at times inconstant in their action; and nothing is more disastrous in salt manufacture, than even a temporary stoppage of the brine supply. On theoretical grounds it was decided by the Madras Board of Revenue, in 1876, not to employ wind-mills for the brine service of the Coromandel salt stations. One experimental attempt of the kind was made by a merchant, and proved a failure; but in this case the machine used was very roughly constructed, and in some respects peculiar; the sails worked in a horizontal plane, and the motive force was expended on two pumps working simultaneously. It was more a trial of a new machine than anything else. In Holland, wind-mills are commonly used for pumping. There is a tradition in Tranquebar, one of the best preserved of the old Dutch Settlements in India, that the Dutch used small portable Archimedian screw pumps, worked by wind-power, in their salt manufactories.

Wind-mill pumps are much employed in the west of France, and other places where coal is dear. At Pornic some of the houses are supplied with water by wind pumps, erected on towers. These pumps are manufactured at Nantes, and seem to answer their purpose remarkably well. The sails are fixed in a horizontal plain. It is probable that the enormous force, generated by the sun's heat, which now runs to waste in the winds, will be, some day, turned to account with magnificent results; but at present the problem is quite unsolved. As far as salt manufacture is concerned, wind-mills are well worth further trial, considering how closely the cost of salt manufacture is associated with the expense of raising brine. At the same time, practically, the subject requires great caution, a thorough knowledge of the work to be done, and the power of the wind to do it. The horse-power of a wind pump depends upon the force of the wind. Thus if V be the velocity of the wind in feet per second and A be the area of sail exposed, the horse-power is given by the formula $H.P. = \frac{A V^3}{1,080,000.}$

Wind-mills are not now used at Hayling Island since the salt works exist no longer. About four years ago the last proprietor died, and with him the historic industry of the island ceased. The salt pans are now converted into brickfields.

Manual Pumps.—In India, brine for salt culture is raised exclusively by cooly, or manual labor, with the assistance of hand machinery.

Slung baskets are often used for this purpose. From two to eight men work together in pairs. Each pair swings between them, a wicker basket, slung at the end of two long ropes. All start together; dash the baskets one behind the other into the brine; lift them up full; and discharge them with a swinging motion, and machine-like regularity, on to the higher level. Each pair will lift about 315 cubic feet per hour, through a height of from three to four feet. Slung baskets are not often employed for higher lifts, as the lower the depth, the greater the area required for the swing; they can however, under favourable circumstances, raise brine through eight feet. Their use entails numerous delays from baskets getting out of swing, ropes breaking, baskets leaking, etc. They have the advantage of being very cheap, and easily replaced at a moment's notice.

Picotahs.—Various forms of picotahs are commonly employed for raising brine in India. A picotah consists of a tall post, planted in the ground, on the top of which a long, horizontal bar, pivots in a vertical plane; one end of the bar overhangs the brine source, and to this a rope and bucket, or earthen vessel, are attached; the other end of the bar is weighted with a suitable counterpoise. The operator takes the rope and draws down the bucket end of the bar, until the vessel attached, reaches the water, and is filled; he then pulls it up, and is much assisted in so doing, by the counterpoise. Another, double, or two-men power picotah, is made more solidly than the last. In this form, a second person stands on the pivot of the horizontal bar, depressing the bucket end to the well, or brine source, by taking a step towards that end, and lifting the brine by turning back, and walking out towards the counterpoise. These picotahs are capable of lifting brine many feet; indeed, the only limit to their power of lift, is the height of the vertical, and length of the horizontal pole. Sometimes two or even three men, perched aloft, tread up and down the horizontal bar, whilst one man, below, manages the bucket. One of these two-men picotahs will raise 317 cubic feet of brine per hour, through a lift of five feet. A "single picotah" will raise 228 cubic feet through the same height. It will be seen that the single picotah worked by one man is the cheapest of the picotah series. Picotahs, as roughly constructed in India, frequently come to grief;

but on the whole, they stand rough work well, and give greater satisfaction than any other form of pump.

Hand-pumps.—A $10\frac{1}{2}$ ft. lift-pump tried in Indian salt manufacture, worked by three men, furnished only 294 cubic feet of brine per hour. Machinery of European construction seldom succeeds in India, unless under the direct supervision of Europeans.

The merits of the most common pumps in use may be compared as follows:—

Machine.	Lift in feet.	Discharge per hour.	Work, per man, in cubic feet lifted per hour.
Single Picotah..............	4	228	228
Double do.	4	350	175
Slung baskets................	4	315	157
Treble Hand-pump.........	4	350	116

The single picotah, the best pump in ordinary use in India, yields 228 cubic feet of brine per hour over a four foot lift. The French mule-tampon yields over 7,000 cubic feet under the same conditions. It may assist pumping calculations to state that 363 cubic feet of brine irrigation, per acre, equals 0·1 inch of brine spread over that surface.

A natural motive power exists at most bay salt works, which has not, hitherto, been turned to good account in driving pumping machinery; that is the tide. Tidal Mills, although not much used at present, were common in Venice from 1078 to 1107, as is related in "*Beckman's History of Inventions,*" 1814, vol. 1, p. 245. Even as late as the present century such mills were in use in Spain, France, and England. It is essential for a tide mill that there should be a tidal rise of some feet, so as to get a good race or current. Further, there must be a reservoir, natural or artificial, at the level of low water, separated from the sea by a canal and sluice gate, with or without embankments. When the tide rises two feet, if the sluice be opened, there will be a current running through the canal with a head of two feet, until the reservoir is filled to the same level as the sea. If the sluice gate is closed until the tide falls two feet, and is then reopened, a current of similar strength will flow, in the reverse direction, until the tide is out. Taking the tidal rise as 12 feet, and the size of the reservoir as one acre, and deducting the 2 feet which are not worked, we get an acre 10 feet deep, or 435,600 cubic feet of water. This quantity passes in, twice, and out, twice, in 24 hours.

Now as 884 tons falling 24 feet in 24 hours is a horse power, the theoretical force of the tide with 2 feet fall, is 4·5 horse power, per acre of reservoir. Ten acres of reservoir should give 45 horse power for 20 hours out of 24. The alteration in the direction of the current can be got over by mechanism which makes the motion conveyed to the driving shaft, constant; and the alteration of level by flotation. Some years ago a tidal mill was constructed on the banks of the Thames, at East Greenwich. It had a water way 40 feet wide and its reservoir area was four acres. The water wheel was a cylinder 26 feet long and 11 feet in diameter, with 32 float boards, arranged in four divisions to equalize the action of the water. The axes of the wheel carried at each end a bevil wheel, communicating motion to other bevil wheels, differently set, acting independently on a vertical shaft; one turning it at the flood and the other at the ebb, both in the same direction. The water wheel and parts connected, weighing 20 tons, were so mounted as to rise and fall with the tide. I went to look for this mill in 1881; but found that the tidal works had long been replaced by steam.

Sir R. Kane, ("*The Industrial Resources of Inland*," p. 112,) prefers the use of a turbine wheel for tidal mills. It is peculiarly the machine for economising tidal power; and might be expected to give at least three horse power for each acre of reservoir, as described above. For further information on this subject, see Belidor, Gregory, Barlow, and Aldini in the *Penny Cyclopædia* Article, *Tidal Mills*.

The Japanese may teach us a lesson in the utilization of running water as a motive force for pumping. They have a most ingenious and economical water lift, in use for irrigation purposes all over the country, whereby the streams are made to pump water up to the fields. It consists of a light, wooden water-wheel, fixed on an axle, across the stream, which turns it. A long, leather bucket is attached near the circumference of the wheel, in such a way, that at each revolution the bucket is dipped into the stream, filled, and carried to the top, where it discharges into a trough placed at a convenient distance. The lift may be four or five feet according to the diameter of the wheel. The work done varies with the power of the current. The machine costs but a few shillings and works automatically. A number of these wheels placed in a stream, raise, in the aggregate, a large body of water, working day and night, without any supervision.

Soil.—It is a matter of the greatest importance to obtain an impermeable clay soil for high level works. Salterns below the sea level, on ground already saturated with brine, may possess a comparatively porous soil, without ultimately any great loss from leakage. As soon as the soil is saturated with the dense brine from the works, leakage stops, for the strong sub-soil brine is capable of supporting the weaker irrigation brine which flows over it. The tendency is rather for the sea to force its way up through the soil into the works. At Iskapilly, one of the Coromandel Salt stations, situated close to the sea, and in part below the sea level, some old condensers, which had been out of work for three years, presented the spectacle of a series of shallow pools, ebbing and flowing, with the sea. The soil was porous, and the low level condensers noticed, were close to the sea, and felt the pressure of the tide. Brine submitted to evaporation in pans of this description, would take long to concentrate; the sea water percolating upwards into the concentrated brine of the salt pans, would rob it of its strength, and prevent it from reaching saturation. On the other hand, at no great distance from the shore, even in porous soils, the sub-soil brine is stronger than sea water; it may or may not rise and fall synchronously with the tide, but in any case it is the sub-soil brine moved by tidal pressure, and not sea water which rises. The Iskapilly case is mentioned, as it is of interest and has its practical bearing, but it was altogether exceptional. At 100 yards from high water mark, there is no tidal pressure felt at the level of a salt pan; and though the reaction of the sub-soil brine upon the works overhead is not well understood, there is evidence to show that it is not very injurious. The Mediterranean salt gardens are laid out at a foot below the level of the adjoining sea, for the most part on very sandy soil, yet loss

from diffusion or percolation has never been noticed. The Mediterranean, it is true, is nearly tideless, but its shore level changes considerably during storms. Thus, there is another advantage to be placed to the credit of low levels, that the nature of the soil is comparatively a matter of indifference. Sandy soil may be used. Now when the sandy element predominates in a soil, salt is scraped, white and pure, with greater ease than where the soil is an impermeable clay. The elements of alluvial clay are in a much finer state of division than sand, and when the salt crop is raked, as a preliminary to its removal from the crystallizing beds, the disturbed clay sends up a cloud of fine suspended particles, which settle on the salt, and give it a dirty tinge, black, ochreous, or lateritic, as the case may be. Sand, on the contrary, is larger grained and not so easily disturbed. It settles down again more rapidly, and its colour, too, approaches so near to that of salt, that what little of it may be scraped is unnoticed, save on close inspection. What sand may settle on the salt is easily removed by subsequent washing; whereas it is difficult to clean salt which has once been covered with a thin film of clay. The salt scraped from the French crystallizing beds is much whiter than that gathered from the Indian high level beds. The former rest on sand; the latter on clay.

High level salt gardens require a good stiff plastic clay for their formation. Marly clays, containing lime, serve better than common clays. The Coromandel salt pans are, for the most part, laid out on two varieties of clay. One black, and greasy looking, called carbonaceous clay, which is very plastic, and forms water-tight beds, but which degenerates in time, under the solvent influence of brine, into a thick black mud, injurious to the salt. It contains a little lime, but is not so good a soil for salt works as the

next variety, ochreous clay. Red, or ochreous clay, is also a species of marl, coloured by iron salts. Both of these clays split up into irregular cubical fragments, when spread out and dried in the sun; generally they turn paler in colour when dry; and they often exhibit an efflorescence of lime, salt, or soda, on the surface. Such clay marls are commonly found in the Coromandel salt swamps; if not at the surface, not far below it. They often contain shells, and are then called shell-marls. The surface soil of many of the Madras salt works is a species of loam, a mixture of clay, sand, and salt-dust, which, though permeable, is capable of being worked up into staunch compartments. Neither of the clays, above mentioned, are free from sand. Some specimens of carbonaceous clay contain as much as 10 per cent. of sand; and it is not uncommon to find from 20 to 30 per cent. of sand in ochreous clay. The presence therefore of as much as 30 to 35 per cent. of sand, in clay, need be no bar to the selection of such a site for salt manufacture. Practically such clays are made use of for the purpose, without apparent injury; and as far as laboratory experiments go, they may be made perfectly water-tight, and moulded into any shape, by hand pressure.

As it is important to know the percentage of sand in the soil when prospecting for salt sites, the following rough method of analysis, quite sufficient for the purpose, however, is here given. Take a sample of the clay, dry it, pound it fine, and re-dry it with artificial heat, so as to drive off all its water; then weigh off 1,000 grains. Place this 1,000 grains in a flask or pan, add sufficient water, and boil over a fire for 10 minutes. Next pour the stuff into a long glass vessel, washing out the boiling-pan for this purpose, and pour filtered water on it through a long glass tube; the clay rises in a cloud which muddies the water and overflows the vessel, the sand remains at the bottom. As long as muddy water appears, continue pouring in fresh water; when nothing but sand remains, dry it carefully, and

calculate the percentage. Clear fresh water will do, if filtered water is not at hand. In the fresh state, these clays have been found to contain from 20 to 30 per cent. of water, and often two or three per cent. of sodium chloride. The colouring matter of the clay is very apt to impress itself on salt crops; it is good, therefore, to select a light coloured clay, if there is any choice in the matter.

To enable one to form a correct opinion of the value of the site as regards soil, pits should be dug at intervals of 300 yards, and the stratification examined in the sides of the pits. As long as there is a foot of good clay on the surface, it matters little what the sub-soil may be like; but clay sites are often irregular, and thin off at points, exposing beds of sand; and sometimes sand crops up to the surface at most unexpected places. In all such cases the sand must be removed from the surface, and a foot or two of clay laid down instead. Pits and hollows may be afterwards filled up.

The following Table and the accompanying notes, are extracted from one of the author's reports to the Board of Revenue, Madras, on the subject of the Tuticorin salt swamp, now, one of the best salterns in Southern India. It gives an idea of what a good site for salt manufacture is like. In India, sub-soil brine, either alone, or in combination with sea water, is much valued in salt manufacture. The Tuticorin site, it will be noticed, possessed a strong supply of brine. This swamp is, at the north end, within 200 yards of a small estuary or arm of the sea, and is, throughout, from one to two feet above high-tide level. At the surface there is a thin layer of loam, which rests on a stratum of clay, the latter well adapted to the formation of impermeable salt beds. The sub-soil consists of firm, yellow sand, passing below into silt, which contains rather a plentiful supply of brine, averaging 14° Beaumé in strength.

Eight exploratory pits, sunk in different directions, to examine the soil and sub-soil, &c., cut from above downwards through the different strata, shown in the subjoined columns.

The pits were not sunk deeper than about 5 feet, as the question to be decided was whether there was sufficient clay near the surface to form an impermeable floor for the pans, and whether the subsoil brine was strong and plentiful enough to assist manufacture. The depth of brine was measured about two hours after the pits were dug.

last salt pan pest is the prawn. It drills a burrow from the shelving bank of the estuary, into the condenser, and thus lets out its brine. These also are difficult to dislodge, but perseverance in blocking up burrows, and in letting condensed brine flow into infested places, vanquishes them all in the long run, so that in the third month of salt manufacture, they all disappear.

In the marshes about the Spanish *salinas*, at San Fernando, the capital of Isla de Leon, innumerable small crabs are found, the fore claws of which are Andalusian luxuries, and are called *Bocas de la Isla*. They are torn off from the living crab, which is then turned loose, to grow fresh claws for another day.

In Madras, where, owing to the small area of each separate salt property, salt manufacture is never a very profitable undertaking, the natives are averse to occupying lands infested with crabs, as they cannot afford to take time to drive them away. A native salt work is such a small affair, 40,000 to 80,000 square feet in area, that any slight loss of brine makes a sensible difference in the profits. When, after opening out a salt work, crabs attack the crystallizing pans, the natives have an ingenious way of getting over the difficulty. They build at a few inches distance, round the orifice, a small embankment; so as to make a distinct pond, within, but not communicating with the rest of the salt bed, in which the crab has established itself. This precaution answers well enough in small native works, in which the crystallizing brine is far from being saturated. Where saturated brine is used, as ought always to be the case, it will be enough to block the hole, as the crab will instinctively avoid tunnelling into dense brine, which would prove fatal to it. At a place called Pentacottah, on the Coromandel Coast, the natives complain that a *worm* injures their salt works; but the author was unable to find any trace of it, and is inclined to believe that the worm was identical with one of the crab pests, above mentioned.

Labour.—It may seem unnecessary to insist that facilities for obtaining labour is one of the chief requisites in salt culture, and a thing to be borne in mind when selecting salt sites. Yet this is a point which might be very easily overlooked by one unacquainted with the details of manufacture, and

with the ordinary aspect of salt sites. To take the latter first. Suitable swamps for salt culture are for the most part situated in localities unsuited for other industries, so that even if they are adapted to the habitations of men, there is seldom any inducement for men to live in the neighbourhood. Generally, salt swamps are barren solitudes, and often they are devoid of fresh water and of the first necessaries of life. In the saline of *Aigues Mortes,* near Montpellier, water for the use of the work people is obtained by means of an artesian well, sunk through the sand to a depth of 150 feet. Fresh water, within a reasonable distance, is hence an indispensable requisite for a salt site. The use of machinery, especially of steam machinery, will economize labour in pumping; but it does not affect the necessity for abundant and cheap labour, quickly procurable, when harvesting operations begin. No machinery has as yet been invented, either as a substitute for, or in aid of the manual labour of gathering salt. It is all done by hand, either at intervals, or once for all, as in France, according to the system employed. When salt is gathered frequently from the crystallizing beds of a saltern, there is comparatively little to do, and a few men employed on the permanent staff of the works will be able to manage it. The longer the interval, the larger the number of men that will be required; and when salt is only harvested when rain threatens, a large number of labourers will be required at a very short notice. When the circumstances and cost of salt manufacture are examined in detail, some information will be given as to the exact number of men required.

As regards the supply of fresh water, there is some reason to believe that good water may generally be obtained near the sea, by sinking deep artesian wells to tap the subterranean water-ways running out of the land. This has been done with success at several of the French salines. In the French settlement, at Pondicherry, an artesian well

which produces spring water was sunk in 1879, in a most unpromising alluvial flat, near the sea, I believe, in this case, the geological indications were against the probability of success.

Climate.—It is hardly worth while attempting natural salt manufacture at any place, in which at least four months of comparatively dry weather cannot be had. The mere work of preparing the soil for salt manufacture, with the full complement of labour, occupies about four weeks of the dry season. When salt pans are constructed for the first time, it takes much longer, three or four months perhaps; so that very little out-turn can be expected the first year, even in a suitable climate. Occasional light showers of rain are no bar whatever to manufacture, indeed their influence is often favourable to crystallization; but the heavy downpours of the tropics inflict a serious injury. One should have some rainfall statistics of a locality prospected for bay salt works.

The percentage of moisture in the atmosphere has much to say to the profit of salt culture. In the tropics, by the sea, it often amounts to 60 or 75 per cent. for weeks together. Evaporation—the natural force, which renders salt gardens possible—is the slow production of vapour at the surface of a volatile liquid, in this case sea water. It depends upon heat, which accelerates the formation of vapour, by increasing its elastic force. It is retarded by moisture, and diminished as the surrounding air is more or less charged with moisture. If the air were already saturated, no evaporation could take place.

The influence of moisture is to a certain extent counterbalanced by the action of wind. In calm, still weather, however hot, what with evaporation from the salt gardens and the moisture already present in sea air, very little progress is made in salt manufacture. The stratum of air

surrounding the condensers, charged with moisture, is removed so slowly, that evaporation is brought almost to a stand still. The great advantage of wind is, that it carries off moisture as rapidly as it forms. Sea breezes, being moist, moderately retard the process; hot and dry land winds, on the contrary, accelerate it, and do so in proportion to their rate of speed. They remove the moist air from the works, and substituting a hot rarified stratum of air, which assists the formatiom of fresh vapour. Winds, also, by agitating the brine and throwing its surface into waves, at least double the superficial area of fluid exposed to evaporation and consequently its rate. Winds in some other respects, however, are adverse in their action as regards salt culture. They carry dust into the crystallizing beds, and interfere with proper crystal formation, by the motion they give rise to in the fluid. A site, therefore, with a sandy tract to windward, visited by violent and periodic winds, such as the land and sea breezes of the tropics, is to be held in suspicion. If sand-dunes are seen to windward, drift sand is very apt to accumulate in the works, which are also liable to be buried under advancing dunes. Something may be done to prevent accidents of this kind by planting a barrier between the works and neighbouring sand wastes. Precautions of the kind should not be neglected, where the site is in other respects a valuable one, and worth selecting. In India, the screw pine, palmyra palm, cocoanut palm, and casuarina, grow well, with a little cultivation, on such wastes; and in the South of Europe, the eucalyptus globulus has been lately tried with some success.

Where the volume of brine in the different areas of a salt work is regulated by open sluices, and these are carelessly left open during a high wind, the whole arrangement as to depth is upset by the wind, which drives the brine before

it. If the wind and the fall of level act together, the disturbance is proportionately great; the upper condensers empty themselves into the lower and finally dry up.

A barometer, a thermometer, a hygrometer, and some Meteorological knowledge will assist a salt manufacturer, exposed as he is to vicissitudes of weather. Together with these, *local* weather-knowledge is of very great assistance. Crops of salt are often lost, which might be saved by these helps. The author has more than once succeeded in harvesting salt, in the nick of time, by noticing an undue change of the prevailing wind, distant clouds, a dark horizon to windward, a change in the barometer, *up or down*, a slight fall in temperature, and a slight excess of moisture in the atmosphere. A change of wind from the direction of the prevailing trade, with clouds in the new quarter from whence it blows, is one of the surest signs of rain on the Coromandel Coast.

It may not be amiss, in connection with climate, to glance at the health state of salt gardens. Salterns, properly constituted, and in active operation, are without doubt perfectly healthy. There are many men in the South of France who pass their lives in salt gardens. In India, there are thousands who work in the salt-pans for half the year, and that the hottest and most unhealthy season. These men, without possessing any singular immunity from disease, are quite as healthy as other labouring classes, which, considering the nature of their work, the exposure to sun, etc., with feet and legs wet with brine, is saying a good deal. There are certain operations in salt manufacture, as the gathering and storing the crystals, which the natives grumble at a good deal. They have to walk on hard angular salt; their legs sink in mud loaded with sharp edged crystals, and are often wounded; they have to carry baskets of dripping salt to drying platforms; and their bodies presently

become incrusted with salt, like the chimney stacks of steamers, after a storm. These are hardships no doubt; but if the necessaries of life, good food and good water, are obtainable, the men are healthy.

Some people suffer from boils on the legs, owing to the constant irritation of salt dust. Dr. A. R. Platt's Medical Report for 1879, on Chinkiang, on the Yangtszekiang, where there are large salt deposits and much smuggling, mentions that the woman smugglers, who carry the salt in girdles, next the skin, get a species of skin disease, resembling *ecthyma*, with special symptoms of a very aggravated character, which mark it as a unique variety of that disease.

Some salt swamps are what is called miasmatic, that is to say they give off noxious gases; others are known to breed agues and similar periodic fevers; and some have been credited with producing dysentery. Under the influence of cultivation, all of these contagions disappear; and by cultivation, here, is meant salt culture. In France, the eucalyptus globulus is planted to drive off fevers, etc. Salt marshes, or the pools formed in them, at rest, at a high temperature and at a low degree of density, are crowded with living organisms, which multiply rapidly. The author tested the surface temperature of a large Indian lake of the kind, which averaged two feet deep, and which was full of minute life, and green with confervoid growths. Its waters marked 89° F. at 11 A.M.; 92° F. at 1 P.M.; 95° F. at 2 P.M.; and 94° F. at 3 P.M. Its density was 4° B.; and it was then the month of March. Such lakes evaporating and gaining in density, the myriad organisms which they contain, and which are unable to support life beyond 8° or 9° Beaumé, die, putrefy, rise to the surface, and evolve gases of putrescent odour. At about 6° B., the work of destruction begins, and in the hot fluid decomposition is rapidly

accomplished, so that for a few days, or it may be weeks, whilst the brine in passing from 6° to 10°B., the air is pestilential. This stench of putrefaction, which is unhealthy in proportion as it is persistent and offensive, is by no means a necessary concomitant of salt manufacture. On the contrary stenches are unknown in a well regulated salt work. From the time that man's industry has converted a swamp into a salt garden, foul smells and the diseases which accompany them, become matters of tradition. The salt works at *Aigues Mortes* (dead waters) formerly noted for fevers are now perfectly healthy.

It is an open question with Medical men, whether salt swamps are, more or less, insalubrious than fresh swamps. Ziemssen states that marshes formed partly of salt water, especially deltas, are far more noxious than fresh water swamps. Gordon, Jackson, and others, are of opinion that salt marshes are innocuous. My own opinion, from long familiarity with them, is, that they are relatively the least dangerous. The presence of salt tends to check decomposition; and the sea air tends to neutralize it. Actual observation in India shows that salt swamps are not particularly unhealthy.

Before passing on to the practical working of salterns, something must be said of their size. The larger the area of a saltern, the better. In some parts of the South of India, where the salt manufacturer enjoys exceptional advantages; a dry season lasting almost uninterruptedly for three or four months; a high degree of temperature combined with hot land winds which have been known to procure the evaporations of two inches of fresh water in 24 hours; exceedingly cheap labour; clay soils, well adapted to salt works; freedom from expense as regards ground rent; and a free grant of the use of all permanent buildings, canals, embank-

ments and other expensive works which Government provide; salt is made at a loss or at an almost nominal profit. This remarkable, but absolutely true statement, refers to a few places, in which the size of the separate salt properties has been reduced by the native owners to a few hundred square feet. It is clear that a corner knocked off the most valuable garden may be so small that its produce will not pay for the living of a single gardener. Such, or bordering on it, is the state of many small ryots in India.

The salt industry in Brittany, which is said to be dying out, owes its decline, in some measure, to this cause. There is no primogeniture in France, and property is divided amongst all children. At the present time 16,000 hectares of salt gardens in the Loire Inferieur are divided amongst 2,000 proprietors. The consequence is they cannot adopt salt manufacture on a large and paying scale, and they are ruined by the competition of the Compagnie du Midi, some of whose salines on the Mediterranean Coast, cover 20 square miles. Speaking of Indian salt works, Sir Arthur Cotton says: "The native mode of manufacture is open to the same objections as their other operations, *viz.*, that of carrying it on upon too confined a scale, and without capital."

The larger the site the more economically can it be turned to advantage, the greater the opportunity for the use of machinery, and retrenchment in various ways. This is so much of a truism, that it is needless to pursue the subject further. But, it may be said that in salt manufacture, especially, the profit, is directly as the area.

CHAPTER XI.

THE CONSTRUCTION & WORKING OF SALTERNS.

In planning salt gardens, the parts of the work should correspond to the stages of the process of manufacture, in position, area, and level, as far as possible. The stages of the process are two. In the first, water is collected, exposed to evaporation, and purified of suspended matters and of calcium sulphate; it terminates when the brine marks 25° Beaumé. The second stage, or that of crystallization, takes the brine from 25° to 30° B. If the residual salts are required, a third stage is added. For the first, or preparatory stage, as large an evaporating surface as possible is required. In this stage, the object aimed at, is to condense the brine as rapidly as possible to the point of saturation for sodium chloride, 25° B. Here, superficial area is everything; for the time occupied in evaporating a given bulk of water is directly as the depth and inversely as the area of the exposed surface; hence area is rapidity. The depth need be only such, that nine-tenths of the brine having been lost in the course of concentration to 25° B., sufficient will remain to irrigate the crystallizing beds to a proper level, and to carry off, finally, waste products. For the second, or crystallizing stage, a certain number of salt beds are required, large enough, taken together, to hold, easily, all the saturated brine prepared by the condensers. The evaporating earth works of the first stage are termed condensers; those of the second stage, crystallizing beds.

A salt garden is usually made up of a number of separate communicating condensers, falling in level, through which the brine flows, gradually increasing in density as it approaches the last condenser, from whence it gravitates into the crystallizing beds, or is pumped up to them. In the crystallizing beds the saturated brine deposits sodium chloride, in large or small crystals, according to the depth, system employed, temperature, weather, etc. As soon as the Mother-liquor marks 30° Beaumé, the salt is scraped up, or a fresh charge of brine is let on, according to the method of work. In any case after the second charge has been evaporated to 30° Beaumé, the salt is scraped up, heaped, dried, and stored on a neighbouring platform; and the Mother-liquors are removed and cast out; or retained in separate reservoirs, for the sake of the residual salts.

All the works are earth works, consequently their construction should be undertaken after rain, at a time when the ground is still soft and plastic, otherwise the labour and expense of cutting and breaking up hard clay, will be found very great; not to mention the further expense of puddling it for use. All puddling, tamping, and moulding is best done with brine—the stronger the better—and not with fresh water. The salt in the brine appears to cement and consolidate the works. It also opposes a chemical obstacle to leakage, inasmuch as clay already saturated with salt, repels brine containing sodium chloride.

In setting out a salt garden, having ascertained that the soil is good; that, if at a high level, it is capable of being thoroughly drained in wet weather; that it is suitable in all other respects; and that a permanent source of brine, *at least* 2° Beaumé in density, is at hand; the first thing to do is to cast about for a brine reservoir, if one can be had. It often happens that an arm of an estuary,

or a silted basin, can be banked off, and isolated, so as to form a reservoir of strong brine for the service of the works. It will make a great difference in the produce of the gardens, if this can be done early in the season. Natural basins have been thus enclosed at a trifling cost, which have raised the brine supply of salt works from 2° to 6° Beaumé in density, in three months. But at 6° B., the brine contains nearly three times as much salt as it does at 2° B, and, therefore, three times the amount of salt, *cœteris paribus*, can be manufactured from it in a given time.

Embankments.—The next step is to protect the site from inundation by surrounding it with a sufficient embankment. It is impossible to state here, exactly, what amount of embankment will meet the various requirements of different localities. The object is to protect the works from the highest floods, whether by land or sea, which threaten them. In France, the salines are protected beyond the level of the highest recorded floods, and this precaution has been adopted as the result of experience and misfortune. It is a wise example to follow in all places with reference to the known danger which may exist. The earth used in the formation of the embankment is usually taken in such a way as to excavate a canal surrounding the works. This canal, which is used for storing brine, and it may be for carrying salt, in boats, is cut within the embankment, or rather the "spoil" for the embankment is thrown up, on its outer edge. It is most important to press forward this work, having regard to the short duration of the manufacturing season. It will be most rapidly completed if given out in short sections to different contractors, the contract specifying the date of completion.

Levels.—Having plotted out the embankments, etc., and set the contractors to work, the levels will claim attention. Brine has to be conveyed from the condensers to the salt

beds and drained off, or pumped up from the latter, and unless advantage is taken of natural slopes, the necessary fall for the flow of brine, must be provided for by artificial means.

When the levels of the site are sufficiently obvious for the general plan, and its separate condensers alone require levelling, the levels can be accurately ascertained, as in India, by flooding the part, watching the flow of brine, and taking the depth at intervals. In France, at some places, overlooking the sea, an ingenious method of levelling is practised. It is based on the assumption that a line drawn from the horizon, at sea, to the top of a four-foot pole, is horizontal. It is so, practically, for the purpose of levelling a condenser or salt bed, as it rises but four feet in about four miles. Two sticks are cut four feet in length, and their ends are planed at right angles to their length. When these two sticks, provided with plumb lines, are held vertically, one by the observer, and the other by his assistant a few yards in advance, and in the line of sight looking towards the horizon, if the observer looks along the upper edge of his stick at the horizon, the upper edge of the other stick will be just tangent to his line of vision, if the two sticks are on level ground. If the assistant's stick obstruct the view, it is on higher ground, and the portion of the stick between its upper edge and the point where the horizon cuts across it, is a measure of the difference of level. If the assistant's stick is not tangent to the line of vision, but below it, the observer is on higher ground, and he can mark the difference of level by raising the assistant's stick on a peg, until it reaches the line of vision. The peg is then a measure of the difference of level. In France, this method of levelling is left to the work people, who are very apt at it. It is admitted on all hands to be a very quick, simple, and trustworthy procedure. In India, water

levelling is done with great nicety by the natives. A salt manufacturer would do well to have levelling instruments, and understand how to use them.

Relative areas.—Although sea water, in passing from 3° to 25° Beaumé, is reduced to one-tenth of its original volume, or, allowing for loss in earth-works, to considerably less than that again, it will not do to reserve only one-tenth of the whole area for crystallization. In the first place the condensers are always filled before the salt beds; in fact the latter are not irrigated until saturated brine has been prepared. And in the second place, evaporation goes on much more rapidly in the condensers than in the crystallizing beds; on the whole, twice as fast.

The evaporation of brine is progressively retarded as its condensation increases. One inch of sea water will evaporate, whilst a quarter of an inch of saturated brine is evaporating. This is due to the attractive force which the soluble salts exercise on the water in which they are dissolved; and this attraction increases with the density, that is with loss of water and proportionate increase of salts. The following experiment made by the author in South India, in August, illustrates this point. The weather was very cloudy throughout, but a hot land wind was blowing.

Sea water.	1873.							
	29/8.	30/8.	31/8.	1/9	2/9.	3/9.	4/9	
Depth in inches.	3	2	1·4	·9	·5	·2	0	......
Inches evaporated	...	1	·6	·5	·4	·3	·2	In 24 hours = a mean rate of one inch in 48 hours.
Volume	1,000	666·7	466·6	300	166·6	66·6	0	
Density in degrees Beaumé.	3°	6°	9°	12°	18°	27°	...	

The second line, compared with the fourth, shows the diminished power of evaporation, and its rate at the degrees marked.

It is found by experience that the crystallizing beds should occupy at least one-fourth of the whole area; and when a reservoir supplying strong initial brine to the condensers is in use, they should occupy fully one-third of the available area. The condensers then will be to the salt beds as 3 to 1, or as 2 to 1.

As the brine will have to percolate towards the salt beds, where it is used up, as far as salt manufacture is concerned, those beds should be at the lowest level in the site. It will sometimes happen, however, that the lowest ground is the furthest from the road, rail, or river, destined to carry the salt into circulation. In such a case it will be a question of expense whether to bring the road, canal, etc., to the lowest level, or to pump up the diminished brine to a higher flat, adjacent to the traffic highway. Generally speaking it will be found much cheaper, and more convenient in many ways, to adopt the second alternative. The Mother-liquors, too, can then be drained off from the beds by natural means.

Salt platforms.—A site for the salt platforms next requires attention. The store platforms should be between the crystallizing beds and traffic route, or somehow in convenient juxta-position to both. The removal of salt to the store platforms is one of the greatest labours in salt culture. It is expensive in proportion to the distance to be travelled. And the whole cost of salt manufacture, after the completion of the works, is made up of the two items, pumping brine and harvesting salt.

The requisite area for the salt platforms is found, on the Coromandel Coast, by calculating that the yield of salt will be about 2·5 tons, per acre of evaporating surface, per working

month, deducting one month for preliminary constructions, etc. This may be taken as a moderate, but fair estimate, for salt gardens in any tropical or sub-tropical latitude. The platform should be of such a height as to raise the salt itself above all danger from floods. The earth for the platforms is generally dug out in such a way as to form small tanks, or pits, the deeper the better, into which the waste products of manufacture can be discharged. These tanks often yield valuable sub-soil brine. They are also sometimes used for collecting surplus brine from the overflow of beds, after showers.

Condensers.—Having roughly plotted out the area and position of the beds and platforms, the next thing is to consider the number and position of the condensers. These should not be formed on any preconceived theoretical design, however nice, but may be allowed to demarcate themselves as the flow of brine follows the natural undulations of the soil. The first condenser is placed at the highest elevation, and as the brine flows from thence to the salt beds, the intervening area is intersected with clay ridges, in such a manner, that the brine is made to flow over the whole space, without exceeding three or four inches in depth anywhere. Slight irregularities of surface need not, as a rule, be attended to, as long as the average depth of the condensers does not exceed three inches; but small projecting hillocks should be thrown down, and all vegetation cleared away. In a large salt work, the condensers ought not be less than twelve in number; but it will be seen from the foregoing, that their number will be controlled by the necessity for keeping the brine in three inch sheets. The more there are the better.

The partitions between the different condensers are made by puddling up low mud banks, high enough to maintain a depth of three inches in the enclosure, and broad enough to walk upon. When the surface soil is porous, and stiff

clay lies beneath, the *external* walls of the condensers are made of clay, and puddled down to join the clay substratum; in this way, no matter how sandy the surface, the condensers are rendered water-tight. The *partitioning* walls do not require such deep foundations.

The sides of all clay walls and partitions are sloped to an angle of 45°, and well tamped. Any nearer approach to the vertical results in the speedy undermining and crumbling down of the walls, under the influence of wave action. The angle of repose of embankments, acted upon by water, is about 35°. Vegetation is encouraged as much as possible on all mural and condenser partitions, to protect them from denudation. The condensers communicate one with another at their lowest parts only, to prevent lodgment of brine. Where this necessitates the openings being placed opposite each other, a direct current of brine, from inlet to outlet, is often established, so that the body of water in the condenser remains stationary, like a backwater, and is practically useless in the work. To obviate this, it is necessary to run a small mud wall, from the higher opening diagonally across two-thirds of the condenser, so as to compel the brine to circulate round it, before running off. The openings are made in the first instance small, and afterwards gradually enlarged to the size, which is found, by experience, to regulate properly the flow of brine. The brine flows properly when all the condensers, from the pumping station, to the last or finishing condenser, maintain their right levels, and the brine increases perceptibly in density as it passes from one to another. The best way to avoid the injury done by rainfall in diluting brine, is to make the condenser walls just high enough for their purpose and no higher; then, if the condensers are kept full, rain being lighter than brine, will rest on the surface, and overflow

With a clay soil, or with a clay substratum and the impermeable wall, before described, surrounding the works, the condenser floors need not be worked up in any way to protect them from leakage. At first there is always great loss; brine sinks through cracks in the dry earth in a most alarming way; but as the thirsty soil gradually absorbs moisture and swells up, cracks are filled, and leakage diminishes to very small proportions.

Brine supply.—The formation of the condensers cannot ordinarily be undertaken until brine is brought to the high level, or first condenser, inasmuch as the ridges have to be puddled with brine. After flooding, the next step, therefore, is to bring the brine from its source to the first condenser. Should the first condenser happen to be close to the brine source, nothing further is required than to provide, and arrange, the necessary pumping machinery; but should it, as is often the case, be a long way off, a canal, or an aqueduct, will be required to convey brine to it. Whether to prefer a canal or an aqueduct is a question of expense, depending upon levels; but where little cutting is required to form a canal, a canal, with sluice gates, has some advantages. It serves as a reservoir of brine in case of necessity; and it admits of boat traffic. In any case, pumps will be required, either at the beginning of the aqueduct, or at the termination of the canal, unless the pans are well served by the rise and fall of the tide. As soon as brine can be pumped up, the condensers may be taken in hand and finished.

Crystallizing beds.—When the condensers are finished and filled, it will be time to commence making the salt beds. Nothing is gained by beginning them earlier, as they require to be irrigated at once, as soon as they are ready for work, otherwise they crack and spoil; and until the brine has stood

in the condensers for some time, and evaporated to saturation, there is none wherewith to irrigate them. It injures the beds to fill them with weak brine. Weak brine and fresh water filter through prepared clay floors, soften, and unfit them for use. Saturated brine, which has lost in fluidity more than it has gained in weight, disintegrates clay much less than sea water.

In size the salt beds vary greatly in different countries, according to the nature of the soil and the system of gathering salt. Where, as on the Mediterranean Coast of France, salt is gathered only once, in thick slabs, from a hard silicious soil, large beds are used. Even there the size varies from 200 to 3,200 square yards. But where salt is gathered frequently, in a granular state, from clay soils, small beds are always used. In the latter case, the beds are scraped from the side pathways by means of a long rake, as it destroys clay floors to walk upon them. The size of these beds therefore depends upon the area which a man can scrape with a long handled scraper. It will be about 18 × 18 feet. In cutting beds out, care should be taken that all the angles are right angles; otherwise the beds and paths will be unequal and awry. The paths surrounding the beds are made about four feet broad and eighteen inches high. Unless wooden planks are used to protect them from wave action, their sides should be sloped at an angle of 35°. The arrangements of the salt beds in rows, blocks, etc., will be controlled by the shape of the ground. It is a good plan to have them in rows abutting on the salt platforms. The *feeding channel*, for the conveyance of saturated brine to the beds, runs along the high level side of the terrace of beds, and the *waste channel* borders their lower ends.

The feeding-channel should be made large enough to fill

the crystallizing beds in a few hours. It is a common mistake to make it too small. The waste channel need not be so large, as its chief office is to convey away the Mother-liquor.

The next and most important prelude to salt manufacture is the practical work of making the crystallizing beds. Clean salt cannot be made from clay beds, unless the latter are well tamped in the first instance. When harvestings are frequent, the beds require to be re-made after every second scraping—perhaps once a fortnight. Frequent disturbance of clay beds involves loss of time, increased expense, loss of salt, and dirty salt crops. The question arises—Can any cheap and ready substitute be found for clay beds?

Some experiments, on a very small scale, for testing the merits of artificial materials for salt beds, were made for the Board of Revenue by the author, in the neighbourhood of Madras, in 1875. The materials used were Portland cement; General Morgan's hydraulic cement; artificial stone of magnesite; plaster of Paris; a hydraulic cement of the author's; and bricks and lime. The experiments were inconclusive; but as far as they went, they tended to show that artificial beds, on clay works, get disorganized, and will not stand the wear and tear of natural salt culture. Slate, flagstones, and planking, have been proposed for salt beds, and it appears that planks are used in some of the United States salt pans; but such experience as the author has had, tells rather against all artificial works of the kind. They all answer well enough for a time. There is no leakage, and the salt crystals are gathered white as snow; but presently the cement begins to blister and crumble, brine gets underneath and saps foundations, beds sink and crack when walked on, dirt is washed off the pathways into the beds, and the salt crystals are coated with mud.

It is but fair to state that several Engineers have expressed an opinion that artificial beds could be made of almost any of the materials noticed, so placed, on solid foundations, as to maintain their character for efficiency. As regards the experiment alluded to, Portland cement resisted decay the longest; gypsum plaster broke up

first; and the other substances were about on a par. The formation of *magnesite artificial stone*, can be carried out with great facility at salt works, if only magnesite, or magnesium carbonate, is readily procurable. It is a rare mineral however. Magnesite is first reduced by heat to magnesium oxide. It is then calcined in a kiln to drive off its carbonic acid, just as calcite is. The magnesium oxide is then mixed with half its bulk of coarse sand, and moulded in boxes to any shape required. This is then thoroughly drenched with the mother-liquor of salt manufacture at 36° Beaumé. The magnesium oxide and magnesium chloride of the brine combine to form magnesium oxichloride, which crystallizes, and compacts the mixture into a hard firm stone. The materials for a *hydraulic cement* are procurable at most salt swamps. Clay containing less than five per cent. of sand, is broken into cubes of about half an inch, dried, weighed, and ground. One and a quarter times, by weight, of slaked lime is added to and well mixed with the powdered clay. The mixture is made into a paste, and thoroughly incorporated by being ground in a mill. Afterwards the paste is made into small balls, dried, and burnt in a kiln. The burnt balls, when finely re-ground, form the cement. The secret of success is in the final grinding. The finer the dust, the better it sets.

On the whole, of all the materials mentioned, it is probable that planking would answer best for salt beds. It has the advantage of being put down quickly, taken up, or re-placed, with ease, and stored away during the off season. It is just the sort of material required for salt beds; and owing to the antiseptic action of strong brine, timber resists natural decay for a long time. Wooden floors can be fastened down with long pegs driven into the clay.

In the west of France, where salt is made on a clay soil, it cannot be turned out quite clean. The consequence is that Atlantic salt is losing its market, owing to the competition of the brilliant, rail bourn salt, made on the Mediterranean Coast. This state of things has often excited the alarm of the General and Municipal Councils of the Departments of the West. As the result of their deliberations more than 20 different methods of gathering salt have been tried in as many years, but without success. The salt beds have been paved with bricks and tiles, and made with lime mortar and other cements; but after a time all these materials have been attacked by the brine. M. Roulleau, a Salt Proprietor of Vendee, made the best bed with a

mortar of sand and asphalte, or bitumen, in the proportion of 4 or 6 parts of bitumen to 100 of sand. For economy, he states that gas tar may be used instead of the natural product. He first levels and tamps the salt bed, and then applies a layer of his composition to the surface. It is said that manufacture may begin at once, before the stuff is dry. He exhibited his composition at the Paris International Exhibition of 1872, where it attracted some attention. The *Revue Hebdomedarie de Chimie Scientifique et Industrielle*, (7th Nov. 1872,) apparently quoting from the report of the Jury, says, "M. Roulleau has at last found a means of getting the purest salt, and saving the Mother-liquors. His materials are unalterable and may be applied to any soil, at any elevation. The preparation is most inexpensive, rivalling in this respect ancient methods. Mother-liquors, marking 35° Beaumé, are gathered from the beds at a temperature of 18° C. They yield a mixture of salts, the chlorides of sodium, potassium, and magnesium, and the sulphates of potassium and sodium, with some bromides and iodides." Impressed with the importance of this invention, I visited Britanny, the chief seat of salt culture in the West of France, in the summer of 1881, with a view to study this material. Unfortunately it was not known at Le Croisic, Bourgneuf and Noir Moutiers, in Brittany. I met a salt proprietor from Vendee, who had never even heard of it. I took the coast train which runs through the salt pans of Vendee and the lower coast, and saw no trace of it. Finally I came to the conclusion that it had not survived a ten years' trial, and that it was another failure. My own experience teaches me that mud will get into salt pans, no matter what they are made of, hence I was not surprised. Besides, artificial pans are very expensive, even if made with gas tar: and it will generally happen that gas tar and other artificial materials are not to be found within reach of a salt swamp.

Clay beds.—The process of making clay beds is as follows: 1st, remove all vegetation and level the ground; 2nd, if the soil is very hard, dry, and fissured, dig it up to the depth of about one foot and break up the clods; 3rd, let in as much brine as will reduce the floor of the bed, to the depth of six inches, to the consistency of soft mud; 4th, tread and puddle it under foot, until it is so dry that the foot ceases to make an impression on it; 5th, let it set and harden; 6th, as soon

as it shows any signs of cracking, irrigate it with sufficient brine to test the levels accurately, and re-level it if required; 7th, puddle it under foot until it is again dry and firm; 8th, sand it with fine sand, sufficient to keep the rams from sticking, and ram it, or roll it, well; 9th, let it rest and harden in the sun, watering the surface from time to time with a fine watering pot, to prevent cracks. The bed is then ready for use, and should be irrigated at once, before cracks actually develope.

In the Madras Salt Gardens, this method is strictly followed out. It is one that has been handed down to the present salt labourers by generations of ancestors in the same line of business. It has been perfected by experience, and is without doubt the best method of preparing the beds. The whole process takes eighteen days, more or less, according to the weather. Solid blocks of wood are used for ramming the clay in the 8th stage. If a roller is used, it should be very broad and light. Heavy rollers simply injure the bed; the clay doubles up and cracks under them. The less sand that is used the better. Experiments have shown that the more sand is worked into the surface of the bed, and the larger it is in grain, the more rapidly the bed disintegrates. M. Courtois states that one part of lime, mixed with nine parts of clay, sets well under water, and will in three days resist the pressure of the thumb. This addition of lime to the clay has been tried by me, but without improvement.

For the first two years, salt beds, prepared in the manner described, are unsatisfactory. Notwithstanding that a fragment of clay, if taken from the bed and kneaded, will not leak a bit, the bed itself leaks obviously. This, doubtless, is owing to the disturbance of its particles, and their moisture. Time, as well as pressure, is required, to enable its molecules tosettle and set; and as moisture is absorbed, they are bound together by the crystallization of soluble salts. Certain it is that, with time and repeated tampings, old beds produce the most salt; and the difference between old and new beds, as regards salt produce, is so great as to astonish inexperienced hands at salt culture.

I have heard salt workers, in Britanny, say that when *abandoned* salt pans are reconverted to use, it takes about four years to bring them into the same category of productiveness as old pans. The living generation has no experience of *new* pans, since lots of old ones are lying waste in Britanny; but they think a virgin soil would require a still longer time to yield good crops. It should be stated that they do not tamp their pans half as well as they do in Madras.

In India, the crystallizing beds are divided by small clay partitions, one down the centre, and two across, into six equal and communicating compartments. The object of this is to break wind ripples on the surface of the brine; to obtain as much rest as possible for the process of crystal formation. Walls and wind barriers, of sorts, surrounding the works, have been tried, and have been found to do more harm than good. They generate dirt which is blown on to the salt crystals. It is well to peg down about a square yard of planking, in the clay bed, in front of the irrigation opening, to prevent the bed from being cut up by the influx of brine.

In France, the salt beds are composed of a sandy loam, which is compressed by being rolled with heavy rollers before use. The sides of the beds are planked all round to prevent the clay walls from crumbling in. The openings of entrance and of exit, for the brine and Mother-liquor respectively, are wooden sluice gates. In India, openings are cut in the clay, as required, and then blocked up again. In some places earthenware pipes are used.

One of the chief indications in supplying brine to the salt beds is to avoid mud. Hence there is a great advantage in employing wooden aqueducts, or water pipes of some sort, for conveying brine from the last condenser to the

crystallizing beds. If the brine itself is filtered through clear sand, or fibrous nettings, it will further help to preserve the purity of the salt.

In Britanny the condensers communicate with the feeding channel by means of boards, fixed in the clay, in which there are round holes, fitted with pegs, at different levels. As brine is required, the pegs are, one by one, withdrawn, with very little disturbance of the mud. In other places, boxes, open at one end, are used. The closed end of the box is walled into the floor of the condenser with clay, so that the lid is an inch above the muddy floor of the condenser. The open end of the box projects into the channel, which it supplies. In the lid of the box are holes, closed with pegs. This is a most ingenious contrivance. When the pegs are withdrawn, only the clear brine from the condenser flows down into the box, as the last inch, is below the level of the holes, and the last inch contains all the muddy sediment, which is thus avoided. As the brine flows on to the bottom of the box, and glides out through its open end, there is no tearing up of the clay floor. Besides, removing pegs is a clean and easy way of doing the business, and one which does not disturb the clay. If, in addition, a sand filter were fixed in the box, through which the brine would have to pass, every source of dirt would be removed.

If the condensers have been completed and irrigated in good time, saturated brine, or brine about 25° B. in density, will be procurable in the finishing condenser, when the beds are ready.

Manufacture.—From the date of completion of the condensers, sufficient sea brine is pumped into the first condenser, daily, to maintain the depth of fluid in the series of condensers at three inches. The exact amount required will be found by a few days' experience. Theoretically it equals ·5

of an inch multiplied into the surface of fluid exposed to evaporation. As saturated brine is withdrawn from the finishing condenser for the service of the salt beds, more sea water will have to be pumped up from the pumping station. The brine flows slowly, by gravitation, from the first condenser to the last, gaining in strength as it proceeds, until it reaches saturation in the finishing condenser. If it flows too fast, or gathers too deep, in the last or any of the preceding condensers, or the reverse, the openings require to be attended to, made larger, or smaller, as the case may be. Arrived at the crystallizing beds, the practical work of manufacture begins. There are various systems of manufacture.

There are three main systems of salt culture and one or two modifications derived from these:

In the first, or *single irrigation* system, the salt bed is irrigated to a depth of about an inch, it may be an inch and a half, with saturated brine, which is evaporated until a layer of salt crystals, generally a quarter of an inch in thickness, has formed. These are then raked up with wooden scrapers, and heaped on the pathway to drain, and the bed is irrigated with a fresh charge of brine. In the evening, the salt is carried away to the drying platform, and placed in heaps to dry. The crystallizing process takes two or three days. The salt is scraped wet, that is, whilst covered with Mother-liquor; the object being to cleanse it from adherent mud in its passage from the bed. The irrigations and scrapings are repeated about every three days, according to the weather. The Mother-liquors are rejected at every fifth scraping, and at the same time the beds are re-tamped.

There is an advantage in evaporating shallow irrigations saturated brine. Such thin sheets of heavy fluid are scarcely stirred by wind; so that very hard and regular crystals, two or three lines in diameter, are formed, even

during the prevalence of strong winds. This is a matter of importance in India, where the winds are strong, and the size, weight, and solidity of the crystal, are much considered by the Government. The Natives are in the position of contractors. They could, doubtless, manufacture any kind of salt required; but this salt is the smallest grained allowed, and it does not suit them to make larger salt, for it is more troublesome.

Another advantage possessed by this method, is that of quick returns. Its disadvantage is that it necessitates the too frequent disturbance of the clay beds. The clay floors, after every fourth scraping, are ruined, and require to be remade at a considerable sacrifice of time, labour, and expense. Besides, the salt is scraped up from muddy waters, and is seldom clean. Where clay crystallizing beds are in use, it is a bad system of manufacture.

The second, or *accretion* system, combines the advantages of shallow irrigations with the further advantage of rest for the clay bed. Thin sheets of saturated brine, an inch or less in depth, are floated on to the salt beds every four or five days, and evaporated, one after the other, repeatedly, for a season of two months. It follows that the salt is deposited in strata, each stratum being about a quarter of an inch thick, and corresponding to four or five days growth from a single irrigation. Finally the salt crop forms a loose cake, about three inches thick, which is broken up in the beds, whilst yet submerged with Mother-liquor, and collected by hand. It is first heaped for eight or ten days on the path, and then removed to the store platform.

The disadvantage of this system is that the salt cake forms lumps, made up of crystals deposited at different times from successive evaporations, and under different circumstances of wind and temperature. These lumps fall asunder

on rough pressure. The salt lacks cohesion. It does not bear carriage without loss of bulk; and it is ultimately reduced to a finer grain than the single irrigation salt.

In the foregoing systems the Mother-liquor is a source of weakness, rather than of strength. The evaporation of brine in thin sheets is so exhaustive that the other sea salts, magnesium sulphate and the rest, rapidly accumulate in the scant Mother-liquor. As the work progresses, the residual salts confined in the Mother-liquor begin to exercise a potent influence in expediting the separation of sodium chloride from the brine. This action results in a depraved form of crystal; and if unchecked, the magnesium salts are thrown down and adulterate the salt crop. Directly, therefore, the salt crystals begin to lose in regularity of size and shape, and before small, hollow, and flaky forms, actually appear, the Mother-liquor should be drained from the beds, and a little saturated brine let on, for the purpose of still further washing them from magnesium salts.

The density to which the brine is evaporated, in the salt beds, varies a great deal in different places, but it should not exceed 30° B.

Quite different from the above is the third system of salt culture. It is that employed on the Mediterranean Coast of France. The salt beds are irrigated at once to a depth of twelve or eighteen inches with saturated brine, and fresh charges of brine are added from time to time, to keep the density of the fluid from rising above 29° B. The salt is crystallized continuously in one block, from comparatively deep and weak brine. The result of this is that the salt forms large and solid crystals, firmly united into a cake, three or four inches thick. The Mother-liquor is drawn off as soon as the salt is ready to be gathered, and the cake is broken up with shovels, and heaped in the pan to drain for a time; it is afterwards

removed and stacked. This system is undoubtedly the best where the climate is propitious. As there is only one harvesting, it economizes labour very much. In fact, it economizes time, work, and money. It inflicts the least injury on the bed floors, and it produces the purest, cleanest, and finest salt in every way.

The French system takes full advantage of the forcing action of the magnesium salts on sodium chloride. The Mother-liquors are retained throughout the whole process, so that towards the close there is a large amount of magnesium chloride present, which causes the sodium chloride to separate quickly from fresh irrigations; but owing to the depth of brine, constantly maintained, the magnesium salts themselves cannot be thrown down.

It is not every climate, in any case, which will lend itself to the French system. Twelve inches of saturated brine, even in the tropics, take about sixty days to evaporate; and would run the chance of being overwhelmed by the heavy showers which fall in the interval between the regular *monsoon* rains. It is very questionable also whether the wind would not agitate such deep irrigations to such an extent as to prevent proper crystal formation.

The depth to which the actual progressive force of a wave extends, is equal to three times its height from trough to crest, and it gives rise to a certain amount of disturbance at a considerably lower level. Twelve inch irrigations are capable of being thrown into three or four inch waves.

In sheltered swamps and in localities free from the constant pressure of strong winds, the French system would yield the best and cheapest salt; and with attention to the weather and sufficient labour at hand, it could be easily worked. Salt formed by single irrigations is the dirtiest. At each scraping the clay bed floor is raked up and the salt crystals

receive a baptism of mud. The longer salt is allowed to crystallize, undisturbed in the beds, the purer its aspect.

There are modifications of these three systems. The best of them evaporates three or four charges of brine, as in the accretion system, and allows harvesting every three weeks. It is a very fair system, and turns out good salt. It does not tax the clay bed very heavily, and it avoids loss from rain. On the whole, and judging by actul observation of the methods of salt culture in use, the best system of manufacture to pursue in a tropical country seems to be, to evaporate thin sheets of brine, never allowed to exceed two inches in thickness, or 30° B. in density, renewed from time to time as required, until a change in the weather necessitates the removal of the salt. This is the accretion system modified with a view to preserve clay floors, avoid magnesium salts, and minimise the injury caused by rain.

Bay salt manufacturing operations are so entirely dependant upon the weather, that even the system of culture must be changed to suit different climates. As a general rule, it is the wisest course in the tropics to harvest salt frequently. Tropical showers, though not so common as those of Europe, are much more violent. I have often seen Indian showers beat up six-inch brine strata into liquid mud, and reduce them from 10° B. or more, to 2° B. in density. Salt crops in the pans are completely dissolved by such showers. The question is, how may this rain mischief be guarded against? In truth very little can be done. I have already noticed a construction of the condensers and salt beds, which helps to get rid of rain water. I have also furnished some indications of coming rain, which, with local meteorological knowledge would forewarn the manufacturer. The dry and wet bulb thermometers, also, give rain warnings to those that understand them. They show the per-

centage of moisture in the atmosphere, and the temperature of saturation. The nearer they register together, the greater the likelihood of rain. The system of removing salt at the first indication of rain is excellent, where labour is plentiful, and the manager of the works reliable as regards weather knowledge. But when the managment is delegated to inferiors, it is, on the whole, better to draw a hard and fast line, and have the salt harvested at regular intervals, say once a week. This will preclude the possibility of greater damage, resulting from rain, than the loss of one weeks salt. If after showers, the brine in the works is less dense than that at the pumping station, it is best to run it off, and pump in a fresh supply. In the lagoon salt works of Venice, as reconstructed by Baron S. M. Rothschild, deep reservoirs are maintained, into which the brine is rapidly run in case of rain; and from whence it is pumped up again as soon as the weather admits of the resumption of business. At the Onandaga Salt Works in America, still greater care is taken, as the salt pans are covered with wooden frames, running on rollers, which keep off rain. This last plan would be very expensive near the sea. It was feasible at Onandaga, because the *salt springs* were in a forest region. There is really nothing to do when rain falls, but to exercise patience.

Wind Salt.—When there is much wave action, salt is thrown down in the state of powder, generally on the lee side of the salt beds, to which the floating crystals are blown by the wind. Salt crystals are continually forming on the surface of evaporating brine. When the fluid is calm, they fall by their own weight, assisted by their shape, which is that of a pyramid reversed, the apex pointing down; but in a high wind they are drifted together and form pellicles, like 'cats ice,' on the surface of the brine. This wafer-like

salt is gradually forced on to the lee shore and heaped up there like so much snow. There is no objection to it on the score of purity; but it is fine grained and melts easily when wetted, and some traders consequently dislike it.

On the Atlantic Sea board of France, where salt is made precisely as at Madras, this snow salt, as it is there called, is gathered every two days, and used for salting sardines. It is very pure, being the earliest product of evaporation; and generally of a snowy whiteness. It is a pity to see this salt wasted on the Coromandel Coast of India, where the people are wretchedly poor; and after all turn out an inferior quality of salt. It would suit European tastes better than the dirty coarse-grained salt, which is the staple of manufacture. The Tartar inhabitants take several millions of pounds of this salt yearly from the drift salt ridges on the banks of Lake Kosiak.

Often a salt crust forms on the surface of the brine, in deep water, which extends over a third or a half of the crystallizing bed, and almost extinguishes evaporation from that portion which it covers. It wastes power and retards work, one-third, or a half, according to its extent. Such 'wafer salt' floats with ease on the dense brine of the crystallizing beds. It has to be broken up, and removed from time to time, with rakes.

Speaking of the salt lakes, Kaiashack, Kalkaman and Djemantons —situated in the steppes of Asiatic Russia, Tomlinson gives a remarkable example of the growth of this surface salt: "Each of these basins is from 20 to 25 versts in circumference, and the action of the sun produces in them, during the summer season, crystals of salt so numerous, that by mutual contact they at length form thick and solid arches, which like winter ice cover the surface of the lakes. These masses are frequently nine inches thick; the action of the air whitens the upper layers; the lower ones preserve a bluish tint, which in some places assumes a beautiful violet hue; and the solidity of

these crystal fields is such, that horses, chariots, and camels pass safely over them."

At the Cheshire boiling pans the formation of pellicle or surface salt is prevented by the addition of a little oil or resin to the brine. This acts by greasing the crystals and preventing them from sticking together; by floating on the surface and displacing the wafer salt, which sinks accordingly; and literally, as oil on the troubled waters, by reducing mobility. There is no reason why the plan could not be tried in bay salt manufacture, where snow salt is not gathered; but there are prejudices to reckon with, and it would be safer to use the snow salt.

Pink Salt.—A curious phenomenon attends the first formation of salt in natural salt gardens. A bright red scum forms upon the surface of the brine, and is drifted with the wind-salt to the lee shore. A film of it covers the drift salt and gives it a pinkish tinge, which is easily removed by washing. This, at the French salines, is the hydrated sesquioxide of iron. It can only be formed in earthworks which contain iron, as but little iron is found in sea water. Regnault says, that iron is taken up from the soil in the form of peroxide, which causes the yellowness of the early deposit. The peroxide is converted into the protoxide by the putrefactive decomposition of the organisms contained in the brine. This again, is converted into carbonate of the protoxide, which dissolves owing to excess of carbonic acid, and is in its turn changed into the hydrated sesquioxide on exposure to air. The experiments of Professor Zabelaine show that the solubility of iron is increased by salt.

At Shenandoah, County. Va, salt is made from brine springs which are cool and clear. As soon as the brine is warmed, it begins to turn red, and when it is saturated, it has a blood red colour. In this state it is passed into a settling

reservoir, where it deposits and clears. The red substance forms a thick paste, like red paint, on the bottom of the reservoir. It is formed of carbonate of iron, held in solution by carbonic acid, and set free by heat. In some parts of the Madras Presidency, where laterite abounds in the soil, a permanent pink tinge, due to iron is communicated to the salt.

But in many salt gardens, red crystals, from rosy to claret, are found, which do not depend upon iron for their colour. The salt formed in most of the Madras pans, and in the Sambhur Lake in the North of India, is encrusted in the early days of its evaporation by a thin film of matter which gives it a beautiful roseate hue. This is attributed to the development of an algæ. The colouring matter, whatever it is, disappears under the blow pipe. Under the microscope it has a granular amorphous appearance. No distinct animal forms have been discovered in it. In the Madras Salt Works it shows itself at about 25° B., and generally it is first noticed in the morning. At first it is bright in colour, but gradually pink fades to brick red, and brick red to brown, until finally it is no longer distinguishable from an ordinary dirt scum. This takes two or three days. It would appear that the algæ, which springs into life when the brine reaches saturation, is unable to exist under the altered conditions of supersaturation.

This salt algæ has been traced from Cadiz to the United States. In hot and damp summer weather, dried cod fish in the States often exhibit a red colour, which unfits them for market, and entails a serious loss upon the trade. Prof. Farlow, M. D., reported upon this phenomenon at the request of the U. S. Fish Commissioners—in whose report for 1880, his paper appears. This redness disappears in cold weather. He states that it is caused by the presence of a minute plant—the *elathrocystis rosea persicina.* This algæ was found plenti-

fully in the woodwork of the wharves and packing stoves. Prof. Farlow detected it also in the salt with which the fish was cured, *even that coming from Cadiz,* and he suspected that it was of saline origin.

A similarly coloured algæ is found on snow, in the most inaccessible defiles of Mount Shasta, California, and in the neighbourhood of Cross Creek, Holy Cross County, U. S. Red snow is a familiar sight in the polar region. In Greenland, snow fields are often flaked with red. The colour varies from pink to carmine. The melted snow forms a coloured solution *which does not stain.* This algæ is called the *protococus nivalis.*

It appears, at all events, that nascent salt formed in natural works, is liable to red discolouration from two sources—organic and inorganic. This accounts for the very general presence of reddish salt in Salt Mines, and it at the same time strengthens the conclusion that rock salt is the product of solar evaporation.

Salt gathering.—In single irrigation salt works, the crystals are gathered by means of a flat board, set at the end of a long handle—like a rake. The labourer first breaks up the crust of salt, then scrapes the crystals into small heaps, and finally drags them into one mass at the side of the bed, where they are left to drain. Some skill is shown in scraping the crystals from the clay floor without mud, and afterwards in drenching the heaps with brine, to cleanse them from unavoidable stains. Many of the Tamil natives make their beds so small that they can do all this without treading in the bed, and they, doubtless, preserve them longer by so doing. In large beds, baskets are carried in, and the small salt heaps are transferred to the baskets, which are then left on the pathways to drain of Mother-liquor. The crystals are obtained whiter in this way; but it is bad treatment for the clay floors, and even for the salt, as much of it is trodden down into the mud, and lost.

In some salt works on the Mediterranean Coast, where this method of collecting salt in slabs is practised, a species of plant is cultivated in the beds for the better extraction of the salt. This plant is a thick brownish growth which forms on the bottom of the pans to the thickness of about an inch. It is composed of some spongy conferoid tissue which takes up, and is strengthened by, the deposit of calcium sulphate. In the dry state it resembles a firm layer of thick felt, but in the wet state it is sodden and rotten. The salt crystals are deposited upon it and it serves the useful purpose of fending them off from the clay. The salt cakes are afterwards gathered *dry*, without any disturbance of the mud. This growth is very common in bay salt works. It often floats to the surface, and covers large tracts of the condensers. It is wholly out of place in beds which are scraped for salt, at short intervals, in the *wet* state.

Salt crystals should be gathered in the heat of the afternoon. At that time there is the least chance of the crop being adulterated with magnesium and sodium sulphates, which are very soluble in warm brine. These sulphates are occasionally deposited on cold nights, as their solubility is then greatly diminished; the morning is hence the worst time to scrape up the crop. As the day advances, the warmth dissolves the sulphates, and they are no longer procurable.

In the Madras *accretion* system, the salt cakes are generally lifted off by hand. The natives push their open palms into the soft mud, under the salt, and break the cake off in pieces, which they throw into a basket. Here, as the salt is only harvested once or twice in the season, the disturbance of the bed by walking, matters little. When a bed, which has been walked upon, has to be used again, the scraping-board is passed up and down, over its softened and irregular surface, to smooth it. If this is not done, the

next crop of salt forms in the foot-prints and irregularities of the floor, and cannot be lifted off as before, or indeed gathered clean by any means. In the Mediterranean salt works a wooden shovel is used for breaking and lifting up the salt cake.

In Britanny, and in Madras, where the beds are scraped periodically, it is the custom to let in about half an inch of saturated brine when scraping begins. This washes the mud off the salt and enables the workmen to draw it out clean. The great art of getting clean salt from clay beds is the art of scraping. In Britanny one man will scrape 15 beds, 10 by 5 yards, in 4 hours. One Tamil labourer will collect and store from 3 to 4 cwt. of salt a day.

It often happens where clay beds are used, that notwithstanding the care taken, much of the salt gets soiled with mud, in the process of extraction. Such salt can be subsequently purified by washing it in pits containing brine at about 25° B. Saturated brine cleans salt thoroughly; but is unable to dissolve any of it. At the same time it deprives it at once of the greater part of its magnesium chloride. Brine at 25° B. contains only 3 or 4 per cent. of magnesium chloride; whereas the Mother-liquor, with which the crystals are besmeared in extraction, contains five or six times that amount. It is a good practice to dip the baskets into ordinary saturated brine, and shake them a little, or twist them round about, before storage. By this means, if the salt is discoloured, it becomes white; and there is certain to be less wastage with salt so treated, than with salt wet with Mother-liquor. Timed with a watch, Indian labourers take about three minutes to shake a basket of mahogany coloured salt, until it is as white as need be for table use.

In all cases salt is drained at the bed side before removal to the store platform. As salt is gathered in the quick systems, every crystal dripping with viscous brine, containing 16 or 17 per cent. of magnesium chloride, it is very important to dry it well before storage; otherwise the magnesium chloride, absorbing moisture, causes considerable loss in store.

If the salt is placed in baskets, ranged along the pathways, as soon as removed from the beds, it will keep clean. This necessitates a large number of baskets; but baskets are cheap, and it will be found a real economy to provide them abundantly. A good deal of salt is lost at each scraping—a large amount at the end of the season—through heaping on muddy pathways; and what is gathered is more or less soiled.

The operation of salt manufacture which requires the greatest amount of technical skill is that of gathering clean salt. In France, skilled workmen on the establishment, gather the salt from the bed; contractors take it to the platform and heap it. In India, certain men, only, of those employed on the general works of a saltern, are allowed to rake up the salt. Upon their skill depends the whiteness of the salt. If their art be good, the clay bed will yield up salt without mud; but, if the contrary, the salt will be filthy. A few men, here and there, in Britanny, are celebrated for their skill as salt scrapers; and their salt is in great request, owing to its purity.

Drying.—In the Madras Presidency, salt is heaped in small mounds on the *salt platform*, and allowed to drain and dry for a variable period, sometimes extending to three months, before it is finally stored. This is in addition to the drainage it gets at the bed side. In France it is stored at once. The large salt heaps go on draining and drying

indefinitely; and it saves labour to stack the salt at one operation. The object at Madras is to expose a large surface to the sun to dry. But salt containing magnesium chloride—bay salt of any kind—dries in a very parodoxical way. It absorbs moisture from the atmosphere, and magnesium chloride thus dissolves, and drains away. As long as it contains magnesium chloride, it will not *keep dry*. You may expose it to the sun and dry it apparently; but as soon as conditions alter, it will again take up moisture. In fact drying it in the sun only delays the elimination of magnesium chloride, which must be removed by moisture. The longer salt is stored, the more this deliquescent salt drains away, and the purer and drier the salt becomes. Hence inferior salt improves by keeping. It has been often noticed that bay salt is bitter when freshly made, but that it loses this taste after being some months in store. It is not just, therefore, to sell bay salt until it has been some months in store, notwithstanding that there is a certain amount of wastage of good salt in keeping it.

Salt storage.—Salt is stored in large stacks, on raised platforms. The platforms have generally a convex, or ridged back, to carry off drainage from the stacks. Sometimes they are flagged, or tiled, or boarded, to preserve the salt from dust, and the bottom salt from mud. In Madras, it is the custom to heap forty-four tons of salt to each stack; but such small heaps involve a waste of space; are difficult to guard—as in a large store they form a multitude of lanes and hiding places; and where salt is in the open, they offer a comparatively large surface to the rain. At the Sambhur Lake, the salt is stacked in conical, or oblong pyramids, with sides sloped to an angle of 36 degrees, each containing from 500 to 1,000 tons. From numerous experiments and observations, it was found that the angle of

repose of the coarse salt obtained from the Lake was 36 degrees.

These heaps are not covered or protected from the weather in any way, further than that their surfaces are well beaten, and made smooth, with water, to enable rain to flow off readily. Their loss from rain is estimated at two or three inches of surface salt, annually. The Mediterranean salt platforms are long raised causeways, from five to six feet high, and about ten yards broad on top, flanking the salt beds on one side, often flanked by a navigable canal on the other, and generally traversed by tramways in connection with the nearest line of railway. Some of them have tiled floorings, marked for salt heaps; others are boarded; and others again are merely gravelled, and rolled hard. On some, the position of the salt heap is marked out by a low stone wall, forming a three-sided enclosure; on others the same thing is indicated by a similar arrangement of boards. The great bulk of the salt is stored in the open air, in the masonry or wooden frames noticed. Formerly, reeds, rushes, and straw, were used for covering the salt, but now they are discarded, at most salines, in favour of tiles. Besides the superior cleanliness of tiles, the wastage, which was formerly about 10 per cent., has been reduced so much as to be inappreciable. So clean is the salt that it is taken at once from the heaps, and ground down in mills, for table use, without further preparation. The tiles are two feet long by one foot broad, and are bent or curved at right angles to their length. They weigh seven kilogrammes, or 15·4 lbs. English, and cost 90 francs a thousand, or less than a penny each. Table salt, ready ground for use, is always stored in covered buildings; coarse salt, for fish curing and for the manufacture of soda, is stacked without protection, like the Sambhur Lake salt. Throughout the northern

salterns of the Coromandel Coast, salt is stored in triangular prismatic heaps, with gable ends, meeting at a right, or at an obtuse angle, roofed in with straw, or with large palmyra palm leaf thatching. In the Report of the Madras Salt Commission of 1876, the heap is described as being "on an oblong base, the transverse section being a right-angled or obtuse-angled isoceles triangle, and the longitudinal section through the ridge a trapezium."

Some skill is required in placing thatching materials properly, so as to ensure good watertight protection; thatch blows off, decays, and has to be renewed every three years or oftener. The inner skin of thatching, after a time, stains the outer crust of salt. Thatching, to be of service, has to be placed at a steeper angle than that to which the sides of a salt stack can easily be trained. The author once saw a heap of leaf thatched salt, broken up for use, at a place called Chunnampett; it was literally riddled with drainage holes, one or two inches in diameter, some stained with mud, and others containing bits of decomposing thatch. This was a very badly thatched heap, however, and one which by no means represents the general efficiency of this protection.

At the salines of Cette, where salt thatching has been brought to some perfection, the work is done in the following way. When a heap is sufficiently dry and coherent, long pegs are driven into it, in rows, about two feet apart. Cords made of *esparto* grass, are then stretched round the heap in parallel lines, and fastened to the pegs. Thatchers then bind down bundles of *rushes* to the cords, in overlapping rows, with bits of esparto twine. When the thatching is complete, it looks well, and keeps the salt clean for a year or so, until it is disposed of.

The general run of thatch covered heaps in India, waste from 5 to 8 per cent. in the first year; but considerably less

in after years. The wastage diminishes owing to the disappearance of magnesium chloride with the first year's loss. The Cette thatched heaps are said not to waste as much as two per cent.; but they contain much less magnesium chloride, owing to the method of salt manufacture there employed. In the Southern salt gardens of the Coromandel Coast, the heaps are convex backed, so that a transverse section of a heap exhibits a segment of a solid circular plane, varying in height and diameter. These heaps are covered with about twelve inches of earth, the outer rind of which is mixed with a little clay to give it shape, stability, and impermeability. Pure clay is not used, as it cracks and opens out with heat. Although one would suppose that an earth covering would rapidly wash off during rain, most of these heaps, though deeply furrowed without, present scarcely any trace of surface wastage within. Loam makes a cheaper casing for salt than thatch, and with but little more staining of the surface crystals than is caused by thatch. In India, thatch is fastened down with large clots of mud. Salt heaps protected by earth coverings are said not to lose more than three, or four per cent., even if they are in store two or three years.

At Croisic, and many other places in the west of France, I have seen the heaps covered with mud from the pans, well plastered down with a spade. They have more to fear from rain than from sunshine in that quarter, hence clay is more required than loam. When the heaps are sold, the outer rind of salt has to be scraped off, and rejected, as it is too dirty for consumption. It is used up, however, for manure.

As salt fuses and forms a kind of slag at a low red heat, the idea of treating the surface of the stacks with heat has occurred to many minds; but the difficulties in the way are so great, that it is seldom done in practice. Captain Dam-

pier remarks of the salt works in the Bay of Campeachy, South America, that the natives cover their salt heaps, built in ridge fashion, with dry grass and reeds, which they set fire to. The heat converts the outside salt into a hard black crust, which preserves the salt in all weathers. This method was formerly practised, also, at the Cape de Verde Islands. At Zipaquera, in New Granada, salt is sold in the form of glazed balls, prepared in furnaces. The method will be explained hereafter.

CHAPTER XII.

BAY SALT AND BYE PRODUCTS.

Although, from the nature of the process, bay salt works are unable to turn out such marked varieties of salt as we find in the Cheshire market; still, as regards grain, there are several kinds resulting from the different systems of manufacture employed. We shall see, presently, that at some salt gardens in France, further changes are artificially wrought on the bay salt crystal to make it conform to commercial standards. At most of the French *salines* on the Mediterranean Coast, for example, salt crushing mills are at work, which grind the ordinary bay salt to a fine white powder, quite good enough for ordinary household use. Superior qualities of table salt are made by *lavage,* and *rafinage,* as will be noticed later on.

The single irrigation system, described in the last chapter, yields small crystals, about a quarter of an inch in long diameter. The accretion system turns out lumpy salt, mixed up with the debris of similar crystals. The lumps vary from the size of a pigeon's egg, to that of a hen's, and are irregular in shape. The French Mediterranean salt, which is the longest crystallizing, is also the largest. Fragments of salt cake, two to three inches thick, are sometimes found; but as a general rule the cake breaks up into a mass of large crystals, many of them an inch in diameter. With the exception of what is called snow salt, *all* sea salt is large grained. The smallest

salt, or that produced by single irrigations, is as large as what is known as Sunday salt at the English boiling pans, *i.e.*, salt which has had the extra twenty-four hours of Sunday allowed for its growth. This, of course, results from the length of time it takes to crystallize. Owing to the agitation of the brine in exposed pans, it is very irregularly crystallized, that is, the cube is never perfect. Bay salt is always pyramidal in shape; and *hopper* salt, as it is often called, is characteristic of solar evaporation. In some salterns, where it is an object to get cubic crystals, the salt is raked in the beds from time to time to expose fresh surfaces to crystallization.

The colour of the salt depends on the nature of the soil from which it is scraped, and the skill with which it is gathered. As a general rule it is stained brown or pink; but much bay salt is gathered nearly white; that from the French Mediterranean salines is perfectly white. Even the purest bay salt is absolutely opaque: differing remarkably in this respect from rock salt. It seems probable that this is due to the incorporation of dirty Mother-liquor in the crystal, between the lamellæ. Salt crystals formed in clean artificial beds, made of cement, etc., possess the quality of translucency in a very remarkable degree, as compared with clay-pan salt. Air bubbles, in the salt crystal, also cause opacity. This may be noticed on a large scale in pieces of ice. Dumas observed that the rock salt of Wieliczka, which contained gas, was opaque in proportion to the amount of gas it contained. I have seen sea salt, formed in deep brine pits, near the sea, very translucent, and blue in tint, much resembling ice. Well-made bay salt is hard and firm, difficult to break down between the finger and thumb, and heavy for its size. When badly made, it is hollow, light and friable.

Bay salt generally feels quite greasy on first removal from

the salt bed, owing to the magnesium in the Mother-liquor; but after it has been sometime in store and the magnesium chloride has drained away, it should feel dry. Not a bad test for moisture is to grasp a handful of salt and let it fall from the open hand; if it be moist, a number of grains will cling and the hand will feel greasy; if dry, the contrary. The Madras Salt Commission in 1875, weighed a large number of specimens of sea salt from different Madras salterns. The salt examined was poured lightly into a cubic measure. The Commission found that it weighed from 608 oz. to 832 oz. per cubic foot. It will be noticed that the mean weight is about one-half the density of rock salt, which, at the "Mayo Mines" weighs 1,488 oz. to the cubic foot.

The general run of Indian bay salts, as exhibited in the following analyses, are inferior to the average of European bay salts, chiefly however, in the matter of magnesium chloride and its inseparable adjunct, water. But the salts analysed by Drs. Macrae and Hazlett, were ordinary commercial crystals, which had been recently made, and in no sense selected. It does not appear how long the other salts had been in store, the most important point to consider in making a comparison, as salt loses nearly the whole of its magnesium chloride and moisture in the course of three or four years storage. Again, insoluble matter, or dirt, has taken down the percentage of sodium chloride in some of the Indian Bay salts, considerably; for the reason that some of them were common *Bazaar* specimens; and others had travelled several hundred miles to the analyst. Apart from moisture and dirt, Tuticorin salt would take a high place for purity, anywhere. It is not fair to institute a comparison between Lymington Cat salt, and other bay salts, as the former was refined artificially. The Cadiz salt, in the foregoing list, was also apparently refined, or *selected.*

Analyses of Bay Salts.

Districts.	Moisture.	Insoluble matter. Inorganic.	Insoluble matter. Organic.	Sodium Chloride.	Magnesium Chloride.	Magnesium Sulphate.	Calcium Sulphate.	Analyst.
Cutch	3·98	3·36		90·35	0·20	0·38	1·73	W. Macrae, M.A., M.B., Madras Army.
Goa	10·80	2·92		81·85	1·46	0·81	2·16	
Canara...	8·60	4·52		83·26	1·37	0·73	1·52	
Average of 3 specimens of Ennore salt...	5·21	1·03		88·87	1·83	2·35	0·71	
Mixed Chilka Lake salt, 8 specimens ...	7·45	2·791	0·092	86·14	2·04	0·04	1·41	Dr. Hazlett, Madras Army.
Bombay salt from Ghorebunder works ...	3·85	2·702	0·059	91·08	0·61	0·09	0·68	
Tuticorin salt...	3·03	1·085	0·091	94·18	0·47	1·18	0·13	
St. Ubes, Portugal	1·95	0 10		96·50	0·32	0·25	0·88	Karston.
2nd Sort do.	...	2·45		95·19	...	1·69	0·56	
Figueras, Spain	4·20	...		91·14	0·70	3·54	0·33	Berthier.
Cadiz	0·30	0·27		98·45	...	0·65	0·33	
French Mediterranean	...	...		97·20	0·40	0·50	1·20	
Lymington	...	0·20		93·70	1·10	3·50	1·50	Henry.
Do. Cat salt	...	0·10		98·80	0·50	0·50	0·10	

Refining.—At Salcoats in Scotland, Croisic in Britanny, Lymington, (formerly,) and other places, bay salt is manufactured in its first stages by natural, and afterwards by artificial heat. At Croisic, indeed, the salt is first made in the open air, and then brought to the refining houses to be boiled, and refined. In this way a very superior class of salt is produced which is held in the highest estimation in France, and always specified in Government contracts for salt. This esteem, however, in a measure rests on the fallacy that Ocean salt is purer than Mediterranean salt, which is true only of badly manufactured, and unrefined samples. The salt is brought by water from the salines to the refinery pier at Croisic, a distance of about two miles, in lighters, with covered hatches. At the pier the salt is hoisted out of the lighter by means of a crane and box capable of holding 300 kilos of salt. The motive power is furnished by two horses which run out and hoist the box over a waggon, into which the salt falls, when the catch at the bottom is knocked out with a hammer. The waggon runs on a light tramway. It is drawn off to the refinery as soon as its load of 1200 kilos of salt is complete. At the factory salt is refined either by boiling or by washing.

At the boiling house, or *rafinage*, first the salt is dissolved in clear sea water, until the brine is saturated. This brine is then passed through enormous funnel-shaped filters, made of strong cotton sheating, to clean it. Then the brine is boiled in iron pans, in size about 15 feet by 5 feet, and the salt is prepared precisely as at the Cheshire boiling pans, to be noticed later.

At Lymington, in Hampshire, the brine was made to traverse a series of condensers before it was boiled, and the dropping Mother-liquor from the troughs was caught on upright stakes, on which, in time, large masses of salt, called

salt-cats, formed. This salt-cat was very pure, containing as much as 98·80 per cent. of sodium chloride. The Lymington salt pits are now abandoned.

At the washing house, or *lavage*, the salt goes through a more complicated process, which, as far as I am aware, is unique and a speciality of Croisic; and which, I believe, has never been described in print. The *lavage* is a lofty building, packed full of strange looking constructions, which extend from floor to roof, and furnished with a steam engine and its accessories. The process is conducted as follows:—Tram waggons bring in the salt, and tip it into a shallow pit. An endless chain of buckets, similar to those used in dredging operations, dips into the salt and carries it up to the roof, where it is discharged into a sloping trough. In this trough, a long wooden bar, studded with blades like those of a screw propeller, revolves by steam. A *pipe*, ascending from the steam engine, discharges clear saturated brine into the top of the trough. Here the salt is beaten up with the brine, as it flows down to a set of crushers at the lower end. The crushers are two iron cylinders, working against each other, through which the salt is forced, and crushed to a fine powder. From the crushers, a thick salt paste flows through a descending series of zigzag troughs, in which it is again agitated by beaters, until it reaches the ground, where it falls into a tank. Into this tank another series of revolving buckets dip, and dredge the salt paste up to the roof again; in doing so a great part of the water falls back through minute perforations. These buckets empty into sloping, drainage troughs, which permit the greater part of the fluid to drain through their canvas bottoms. They shoot the salt out on to a raised platform, on which a large halix of steam pipes is coiled. The salt covers up the halix and there lies draining and drying by steam, for about 24 hours, when it is

ready for market. This salt is not quite so fine as Cheshire table salt; but it is sold for table use in France, and is of excellent quality.

It may be well to enquire here, what are the kinds of salt for which there is a demand in commerce, and how far bay salt works are capable of meeting that demand? At Cheshire, which is the centre of the trade, there are three varieties of salt turned out, as regards grain. The first is "fine," or stoved salt. It is supplied for table use, and for the preservation of butter, which requires a very fine grained salt. In Holland, where butter and cheese making form a large industry, fine salt is known as "butter salt." This salt can be made perfectly well from bay salt, by boiling. Lavage salt comes very near it; but is not so fine. All other naturally formed sea salts, however, even "snow salt," are larger grained. Next we have *common salt*, a larger variety, but still smaller than ordinary bay salt. "Lavage" and "snow salt" are both smaller than "common salt." It is the staple of the trade, and is used for nearly all the purposes for which salt is required, enumerated in the chapter on Arts and Manufactures. Coarsely grained bay salt, thoroughly dried, could replace it without serious inconvenience, if as pure as Marseilles salt, *i.e.*, containing 97 per cent. of sodium chloride, and free from magnesium chloride. These desiderata can be obtained by high class manufacture, but they are not the characteristics of ordinary bay salt. Finally there is "fishery salt," a large-crystal variety, much the same as bay salt in appearance. This kind is easier made in salt gardens than in boiling pans; but the demand for it is not very great.

All the foregoing varieties of Cheshire salt are made by boiling saturated brine. Rock salt itself is not used, except for chemical manufactures and manure. It is too impure

for other uses. Considering the consumption of coal, the cost of labour, and the capital sunk in expensive plant, the brine-spring manufacturer has little advantage over the tropical bay-salt worker, except that his brine is free from magnesium chloride, the *bete noir* of salt works. Cheshire salt is consequently uniformly pure.

The reason why so much trouble is taken in Cheshire to prepare large and small grained salt, is, because there is a distinct demand for these various sized salt crystals. All the varieties have the same composition, but different physical qualities. Rapidity of solution is proportional to the amount of surface exposed. As the surfaces of cubes are as the squares of their sides, it follows that a crystal of a given magnitude will dissolve four times as slowly as one only half its size. This property therefore, together with the hardness and coherency of the crystal, have much to say to the carriage of the salt.

Small grained salt bears carriage without loss of bulk from mechanical friction. It is used as an antiseptic in packing smoked provisions, and for inland sales. On the other hand, it is the quickest to dissolve in the presence of moisture, owing to the multiplication of exposed surfaces.

Large grained salt is, therefore, generally used for packing fish, and wherever a slowly dissolving salt is required. It is also used for exportation.

Other uses of different grained salt have been noticed at page 170 in connection with food preservation. At Zipaquera, in New Granada, salt is fused into balls, to meet a local want. In England a form of salt, called "London patent solid salt" is made in the same way. Turning back to the analyses of rock-salt at page 116, it will be seen that the better class of sea salts, such as those of the French salines, Cadiz, and Lymington cat-salt, are little, if at all, inferior

to the best samples of rock-salt, and that their impurities are almost precisely the same. The similarity of the analyses gives colour to the belief that both were originally formed from the same source, *viz.*, the sea.

Cost.—A few facts and figures with regard to the cost of sea salt manufacture may prove useful. It is rather difficult to arrive at its actual cost from Indian experience, inasmuch as the expenses of salt culture are divided between the Government and the salt ryots. The Government bears all charges for permanent works of all kinds, as canals, embankments, buildings, bridges, platforms, etc., and pay a certain sum to the ryots for making the salt. On the Coromandel Coast, the salt costs the Government, 3 annas 5·6 pies, per Indian maund, or about eighteen shillings a ton. In this cost is included the value of land assessment; payment to manufacturers, or importers; cost of salt received from other districts; works for salt manufacture; establishment; contingencies; police; miscellaneous; works for storage, and revenue purposes; sundry works; interest on value of salt; and general supervision. This cost is much greater than that which would be incurred by the ordinary salt manufacturer, as it includes many items with which he would not be burthened. On the other hand, the cost of salt manufacture to the ryot is less than the ordinary cost would be, since the ryot is relieved of such items as permanent works for salt manufacture, and proper storage, etc. At the Ennore Salt Gardens, in the vicinity of Madras, the largest works of the kind on the Coromandel Coast, the contractors are paid Rupees 12 a garce, or Rupees 2-7 a ton, for salt. This, at two shillings to the Rupee, would be nearly five shillings a ton. Now these salt ryots or contractors, who own the pans, are commonly in the habit of sub-letting their contracts to

a poorer class of workmen, who pay them one-half of the price realized, say, two shillings and sixpence a ton. It follows that the poorer workmen find it profitable to make salt for two shillings and sixpence a ton, the remaining, moiety of the contract price paid by Government. The author is well acquainted with these poor people, and knows that they are satisfied if they pay their expenses, *i.e.*, keep themselves in food, and that food the cheapest rice, whilst working at salt culture. They evidently do so, or they would not take the sub-let contract, but it is very probable that they do not profit to a much greater extent. Taking then two shillings and sixpence a ton, as representing the working expenses of salt culture, one can get a fair idea of its probable cost to a manufacturer, by adding to this sum the sums charged to Government account, under the headings of land assessment, works for salt manufacture, establishment, and works for storage. These taken together, amount, on the Coromandel Coast, to Rupees 1-5 or about two shillings and sixpence a ton. We thus get the cost of sea salt manufacture at five shillings a ton near Madras. These facts are taken from the report of the Madras Salt Commission. This does not represent the cost of salt manufacture carried out on a large scale, with science, capital, and machinery. It is valuable, however, as showing the actual cost of salt made "native fashion."

On the Mediterranean Coast, where the climatic conditions are not so favourable to salt manufacture as at Madras, the Compagnie du Midi, turns out salt at about 5½ francs a ton. This flourishing company possess an enormous extent of salt gardens, scattered along the South coast of France, in which salt is manufactured on a large scale, and with every useful appliance which wealth can command. For many years back they have been gaining ground on the Atlantic

salt workers, whose industry is now rapidly disappearing—eaten up, like Pharoah's lean kine, by the fat kine of the company. The Atlantic works are individually small, and their outturn is insignificant in amount, and comparatively poor in quality. The wonder is how they have ever paid, considering the climate of the Atlantic shore; yet at one time salt manufacture was the chief industry of the Departments of the West. The salt contractors farm the salt gardens from the land-owners. They pay no rent, but give the proprietors two-thirds of the salt, retaining one-third for themselves. The gain of a family is estimated at 250 francs yearly. They are generally poor people, who work as field labourers, when not engaged in scraping salt. One of them, at Croisic, informed me that in the years 1879 and 1880 the salt crop was a complete failure, and in 1881 they gathered a 30 per cent. crop, or about a third of a full crop. Still, many old pans at Croisic are being furbished up, since the opening of the railway in 1879, and the residents are quite hopeful of a coming revival of their ancient trade. Croisic is the centre of the sardine fishery, and there is always a brisk demand for coarse salt there.

The outturn of an Indian saltern in full working order, varies, according to the season and the number of years the salt-pans have been in use, from two to five tons per acre of evaporating surface, per month. Theoretical considerations would lead one to expect a much larger outturn on the Coromandel Coast. For instance, at page 234 it was noted, in effect, that we could obtain twenty-seven parts by weight of salt from every thousand parts of sea water evaporated. At page 266 there is a table of observations showing that three inches of brine will completely evaporate in six days, during the prevalence of hot land winds, which gives a mean rate of evaporation of one inch in two days.

With these two factors and the area, we should be able to calculate the outturn; but the outturn so found would be much in excess of actual results. The loss from leakage in earthworks has to be taken into account; and for the sake of obtaining a practical estimate it will be well to write off 50 per cent. as thus lost. This leaves a yield of 13·5 per mille for every thousand parts of sea water pumped up and evaporated. Now, the mean rate of evaporation on the Coromandel Coast, for the whole salt season, is considered to be one inch in three days, and numerous experiments of the author's confirm this conclusion; nevertheless for the sake of keeping this estimate within safe limits, it will be taken at one inch in five days, or say six inches a month. Taking then one acre of surface, or 43,560 square feet, as the area on which to base the calculation, and deducting 10 per cent. for path-ways, etc., we get $\frac{39{,}210 \times 144 \times 6}{1728.} = 19{,}600,$ cubic feet of brine evaporated per month. A cubic foot of sea water at 83° F. weighs 1022 ounces. The weight of sea water evaporated is, therefore, $19600 \times 1022 = 20{,}031,$ 200, or about 559 tons. Thirteen and a half parts per thousand, or 1·35 per cent. of this, amounts to about $7\frac{1}{2}$ tons, which is the estimated yield per acre. Good pans, in favourable weather, may be worked at this rate; but it is prudent to expect less, even from old and well tried pans.

Works in operation.—Without being able to supply a complete list of bay salt works, a few notes on the better known, are here furnished for those whom this information may interest.

The bay salt works of England and Scotland have been already referred to. They are not exclusively solar works, and hence are in a different category from the general run of those treated of in this and the preceding chapter. Those of Porto Bello near Edinburgh are about the best. There appear to be none in Ireland; probably for want of cheap coal, and owing to dampness of climate.

France.—There are about 82 salines in France, together occupying

48,500 acres, one of these is on the Channel Coast, 36 on the Atlantic, and the rest are on the Mediterranean shore. The salines in the salt marshes of Britanny are the most important on the Atlantic Coast; but unfortunately they are cut up into a great number of small holdings as in India. At Guerande there are 3,000 such shares; at Noir Moutiers, the average size of a separate salt block is 500 square yards, of which the condensers take two-thirds, and the salt beds the remaining third. The beds are in two rows, separated by a feeding channel, and they are worked by the short system, already described. The similarity between the native works in India and those of Britanny, in every respect, is very remarkable, considering that they are so far apart. It leads one to think that early Anglo-Indian officials introduced the Britanny method into Madras. At one time the Indian Civil Service had a pecuniary interest in the outturn of the native salt pans, and would consequently stamp a European impress upon such works. Agricultural terms such as "salt in flower," "salt harvest" and "salt reaping" are common in Britanny. At Guerande, women carry salt in wooden bowls upon their heads, about 50 lbs. at a time. At Bourgneuf, men carry it on their shoulders, in baskets. A whole family makes only about 250 francs per annum out of a salt holding; but they have other employments, and the salt works are of a secondary importance.

In January 1875, the author, under instructions from the Board of Revenue, Madras, visited and reported upon the French salines on the Mediterranean Coast. Le Perrier, and Peccais, the latter better known as Aigues Mortes, were visited; also le Berre, near Marseilles, and other salines on the shores of the great *Etang du Berre; les Vieux salines d'Hyères,* close to the town of Hyêres; *les salines des Pecheurs,* near Toulon; and those of Cette, in the South. All of these are important works, and as they represent the highest state of the art of bay salt manufacture at the present time, a few lines descriptive of them are extracted from my reports.

The Mediterranean salt gardens of France have many features in common.

A French Saline consists essentially of a large tract of waste shore-land, fifteen to twenty square miles in area, at a lower level than the neighbouring sea, protected from inundation, and cultivated for salt. The salt-pans are divided into *Partie Exterieur, Partie Interieur, Avant Pieces, and Tables Salant.* There are also reservoirs

for the winter storage of unexhausted brine. The condensers and reservoirs occupy 78 per cent. of the evaporating surface, the salt-beds, the remaining 22 per cent. A canal brings brine from the sea, or estuary, as the case may be, to the works, and first to the *partie exterieur*, into which it flows naturally by gravitation.

From thence the brine is conducted through the other divisions of the work, partly by gravitation, and partly by pumping, according as they may be at a lower or at a higher level. In each and all the brine is spread out in thin sheets to evaporate. It nowhere stagnates as it has a continuous motion towards the *tables salant*; and its passage is so regulated that by the time it reaches the *tables* it is saturated and ready to part with its salt. The *tables*, or crystallizing beds, are about eighteen inches deep, and boarded round the edges to avoid dirt. The saturated brine fills them up, ten inches or so; and as evaporation proceeds the depth is maintained by fresh increments of brine: for it is the rule never to allow condensation to exceed 29° Beaumé. This continues until a cake of salt about two inches in thickness has formed on the tables. The Mother-liquor is then run off, and the salt collected in the dry state, with wooden shovels.

The whole duration of manufacture, from first to last, is about five months; that is, from April to August or September. The time allowed for salt crystallisation on the beds is three months.

The brine left in the finishing condensers at the end of the season is called *virgin* brine. It is pumped off to reservoirs at a high level, where it remains until the next season. It has a density of about 20 Beaumé. A certain amount of brine is evaporated on separate tables from 29° to 32° Beaumé. It yields an inferior salt, sold only for fish curing and for chemical works.

The soil on which the salines are laid out is a hard porous sand. It is not worked up artificially, to prevent leakage, except at the *tables salants*, which are rolled and tamped. The Engineers consider that the subsoil brine, which marks 12° B, sufficiently protects the other works from leakage.

The tables salants vary in size from 10 × 20 yards, to 40 × 80 yards. Trodden under foot, they feel like well hardened gravel tennis courts; which they resemble also in colour, level, and rectilinear outline. Much engineering skill is displayed at these works in the pumping arrangements, irrigating channels, etc., as also in the weigh-

ment and storage of salt, but these things have been already noticed in the last chapter.

Portugal.—The works of Setubal at the mouth of the Tagus, on the Atlantic, are famous for their salt produce. There are also numerous works near Lisbon, Barroca d'Alva, Aveiro, and Algarve. The annual produce from all amounts to about 250,000 tons. The method of manufacture is very simple. The ground is divided into pans and pathways, as usual, irrigated from a reservoir. In the autumn, the whole salt garden, paths and all, is flooded with sea water to a depth of 50 or 60 centimetres. In the springs the sea water evaporates, and about June the paths appear. The beds are then cleaned out and the brine allowed to evaporate, a little brine being added, occasionally, from the reservoir. As soon as the salt deposit reaches an inch and a half, or so, in thickness, it is harvested, almost dry. This is the first crop. The pans are then refilled for a second crop, which soon forms under the influence of the north east wind, which prevails at that season. The second crop is collected from about one inch of Mother-liquor to avoid magnesium salts. In favourable weather a third crop is sometimes obtained.

The most important Spanish salt works are situated around the Bay of Cadiz. There are other minor works at Torrevieja and the island of Iviza. All of them both export salt and supply it for home use. The Mediterranean Coast, from Santa Maria to Cadiz, is covered with salt lagoons, in which salt is made. The salt of Torrevieja is said to be as good as that of Cadiz.

The Italian works are small and little if any salt is exported. The chief saltern is near Ostia at the mouth of the Tiber. There is another at Comachio, in the lagoons at the mouth of the river Po. The principal Sardinian salt

works are situated at Cagliari, on the margin of one of the finest harbours in the world. Ships are loaded here with ease and despatch; and there is a fair export trade of salt, chiefly to Italy. The chief salt works of the Mediterranean, excepting the French salines, are situated on the island of Sicily, at a place called Trappani. These works do a large export trade with neighbouring countries, Italy, Greece, Turkey, etc.

Belgium and Holland now refine imported salt, chiefly; although the latter once had an extensive export trade in bay salt. A large bay salt factory exists at Cyprus, which turns out about 30,000 tons of salt yearly. Austria in 1876, turned out 344,862 metrical quintals of sea salt. There are salterns on the coast of Illyria, Dalmatia, Tunis, and Egypt; but with the exception of the latter, which have been developed lately, and are now rising in importance, they are intended only to supply local wants. Egypt has magnificent climate and soil resources for salt manufacture, and with skill and capital, it should in time become not the least of her industries.

Bay salt is manufactured in the lagoons of Pechili, and other parts of the coast of China. The method of manufacture resembles that of India, except that the brine flows into the works at high tide. The salt is small grained, dirty, and impure; and is stored in mounds in the open air. There are other works in Cochin China, at Soe Trang, Baria, and Bien Hoa. Bay salt is also made at Nantucket, and along the shores of Cape Cod, in the United States; and on the coast of California. Also at St. Thomas, and Princes Island, Angola, and Mossamedes; the Cape Verd Islands, Algoa Bay, and other parts of Cape Colony.

Madras.—The sea salt works of British India are very numerous, and extensive. In the Madras Presidency, on

the Cormandel Coast, there are fifty-nine salt stations, scattered up and down a line of coast about 1,000 miles in length, extending in an oblique line from about the 8th, almost to the 20th parallel of north latitude. The total area of these works amounts to about 30,000 acres. The total number of individuals registered as holding salt pans, is about 8000.

The average annual produce of these salterns exceeds 230,000 tons. Some evaporate sea water, others back water, and others again subsoil brine, of different densities, varying in strength from 2·5° to 16° B. The manufacturing season is supposed to last five months, but many of the works are situated so far out of the stream of life and commerce, as to be limited by what is called a *dittum*, i.e., a small order for salt, calculated on the average sales of previous years, beyond which limit they may not manufacture. At many stations the limit is small, the salt ryots assemble for a couple of months in the hottest season, turn out the required quantity of salt and go back to their homes.

There are several other large and important sea salt manufactories in the Bombay Presidency of British India, on the borders of the Arabian Sea and of the Gulf of Cambay, and in Orissa, by the Chilka Lake.

In Western Australia salt is made on Rottnest Island.

Bay salt was formerly largely made on the Bahamas and Turk Islands. In several of the outlying islands the inhabitants rely on this industry for a living, but the high rate of duty, levied by the United States, makes it unprofitable, and the manufacture is dying out.

There are large bay salt manufactories in Java, chiefly on the north coast and at Madura. It is made as in India, and in Britanny. The quantity required for Javan con-

sumption is about 32,000 tons, of which 200 tons come from the volcanic springs in the interior. But there is a large surplus of bay salt, which is exported to the other islands of the Archipelago, where it competes with Siam and Madras salt. Some salt is made also on the south coast; but it is inferior, containing so much magnesium as to make it unpleasant and unfit it for culinary use.

Bye Products.—In the last chapter we traced minutely the details of bay salt manufacture by solar evaporation. As a general rule this is not pushed further than the extraction of common salt, and the bye products are allowed to run waste. Some are hardly worth the labour of extraction, and others require for their removal a variety of temperatures, which can seldom be obtained in nature.

The first bye product to form is calcium sulphate, otherwise called gypsum. It forms early in the process of manufacture, before the deposition of common salt. It is deposited, as a general rule, somewhere towards the last of the series of condensers; those in which the brine marks from 17° to 25° Beaumé. The deposit is very gradual, and may be in the first year unnoticed; but in the course of time, it forms a distinct crust on the bottom of the condensers.

The deposit is in the form of lenticular fibrous crystals, set upright, on edge, and closely packed together in a solid gypsum cement. This crystalline crust interferes with the proper working of the condensers, eventually, by altering their levels. Through exposure to the dry air, when the pans are not in work, it blisters up off the soil, and disarranges the depth, level, and capacity, of the condenser. It is removed about every fifteen or twenty years, with pickaxes, as it forms a cake of stony hardness.

Gypsum crystals are capable of being split up in the direction of their fibres into a series of parallel plates. With the blade of a pen-

knife this cleavage can be repeated until the plates are as thin and as transparent as the finest talc. This gypsum, properly burnt and ground, forms so called plaster of Paris. Its composition is $CaSO_4 + 2 H_2O$. Heated to 275° F., it abandons its water, and changes into anhydrous, which, on the addition of water, rapidly re-absorbs moisture and crystallizes into a solid mass. It can be dehydrated in an ordinary lime kiln. Care must be taken not to push the heat beyond the temperature of 275° F., as, if heated to redness, it melts and changes into anhydrite, $CaSO_4$, which will not take up water, or re-crystallize. The burnt crystals require to be ground to a very fine powder to form good plaster of Paris. Plaster of Paris is used for various purposes in the Arts, and in Surgery. In very fine powder, mixed with isinglass, it is applied to the surface of ornamental vases, statuary, &c. It may be coloured with iron, copper or other salts. When dry, the surface of the vase, or statue, is softened with water, and smoothed with pumice stone, olive oil, and hand polishing. It is afterwards painted and baked, and finally polished with cotton wool. If the powder is, in the first instance, set on with a solution of alum, it makes a finer material, resembling marble. True plaster of Paris has the following composition :—

	Parts.
Calcium sulphate	70·39
Water	18·77
Calcium carbonate	7·63
Clay	3·21
	100·00

Residual Salts.—The residual salts, or those that remain in the Mother-liquor after the common salt crop is gathered, are of considerable value; but they require a range of temperature, from five degrees below to about 100 above the freezing point, for their removal. In solar works the upper limit is frequently attained, but for the lower, in the tropics, at least, artificial cold is required. Considering the rapid strides which invention has of late years taken in the production of artificial cold, this branch of salt culture may yet

be much developed. In fact it has already felt an impetus from this cause.

When salt manufacture is carried beyond the point of separation of sodium chloride, for the sake of the residual salts, the Mother-liquors are run off into a deep reservoir, and there allowed to settle, until the changing seasons bring round winter cold to assist in the further operations. These operations cannot be carried out, in full, unless the temperature of the atmosphere falls to about the freezing point of water; except by artificial means. After the abstraction of salt, the Mother-liquor, if still further evaporated, yields three series of products.

1. A mixture of magnesium sulphate and common salt.

2. A deposit of double sulphate of potassium and magnesium.

3. A double chloride of potassium and magnesium.

1. The first deposit consists chiefly of Epsom salts, and is of no great value. It forms even on the hottest days from concentrated Mother-liquor; but the magnesium element is larger at night and in cold weather, owing to its diminished solubility. If this deposit is artificially warmed in its own brine, a good deal of the magnesium will be redissolved; but the common salt will remain and can be removed. If then the remaining solution is evaporated at a low temperature, magnesium sulphate will crystallize out nearly pure.

But the best way to utilize this deposit is to convert it into sodium sulphate, which is used in the manufacture of glass, as a manure, and for making sodium carbonate. At about the freezing point, sodium chloride and magnesium sulphate break up, and reform as magnesium chloride and sodium sulphate. If the first deposit is redissolved in artificial brine, in the proportion of one part of magnesium sulphate to *two* of common salt, and exposed to a temperature

about five degrees below the freezing point of water, four-fifths of the magnesium sulphate will be transformed into sodium sulphate, which deposits in a very pure state. If this double decomposition is produced in the open air, the crystals must be gathered before the warmth of day produces a reverse decomposition, and also redissolves the salts. By this process the brine loses four-fifths of its magnesium sulphate, but it is still very rich in magnesium chloride, which has a marked power of keeping sodium sulphate in solution. On the other hand brine containing common salt, dissolves less of the sulphate than pure water, and it is to neutralize the action of magnesium chloride, and help the sulphate to crystallize out, that the excess of salt is used in the original solution. Sodium sulphate is dehydrated in reverberating furnaces.

Sodium sulphate can be obtained by acting on the Mother-liquor itself, at low temperatures; but magnesium chloride in this case interferes seriously with the reaction. It diminishes the solubility of both the salts concerned, *viz.*, sodium chloride and magnesium sulphate, and forces them to crystallize out. Hence a diminished quantity remains in the brine to be transformed by cold. And what sodium sulphate is formed, does not all deposit, as the large quantity of magnesium chloride naturally present in Mother-liquor, tends to keep it in solution. The best remedy for this is to add a large quantity of common salt to the brine.

The use of sodium sulphate, in the crude state of salt cake, has lately been patented, for the purification of iron. About 12 ounces of the salt are thrown on the surface of the molten metal, for every 4 to 4½ cwt. of iron, during the operation of puddling.

2. When the Mother-liquor reaches 34° Beaumé, it begins to form the second deposit, the double sulphate of potassium and magnesium, with a little common salt. These

salts are separated and collected in the following way. They are redissolved by warmth and *evaporated*, in the heat of the day, for the extraction of sodium chloride; the brine is then run off to a lower salt bed, and exposed to the *cold* of night, for the double sulphate, which deposits almost pure.

Regnault says, "The separation of the double salt into potassium sulphate and magnesium sulphate is not easily carried out commercially, but the salt can be used in the manufacture of alum. It can also be used in the preparation of potassium carbonate, either in the way artificial soda is made, or by Leblanc's process. With this object, one-hundred parts of the hydrated double sulphate, forty-six parts of calcium carbonate, and twenty-six of carbon, are heated in a reverberating furnace. In operating, as for the manufacture of artificial soda, a coarse potassium is obtained, which marks 24 per cent. with the alcalimeter. In dissolving it out with water, and evaporating the liquid, a much richer product is procured, which contains from 55 to 60 per cent. of potash, and which is about as rich as the ordinary coarse potash of commerce. In this operation, magnesium sulphate is destroyed, and the magnesium is left in the insoluble residue with oxi-sulphide of calcium."

3. At about 36° Beaumé the brine furnishes the third deposit, *viz.*, the double chloride of potassium and magnesium. It is questionable whether this deposit can be obtained by natural evaporation, as brine at 36 B. resists evaporation. However obtained, it can be converted into the simple chlorides by exposure to the atmosphere, which liquefies the deliquescent magnesium salt. The magnesium chloride can then be removed in solution, leaving the potassium to be washed, dried, and gathered. The potassium chloride can be obtained purer by dissolving the deposit in boiling water, and evaporating at high temperature.

Almost pure potassium chloride crystallizes out, till near the end, when the double salt falls. If the evaporation is continued, at a low temperature, the whole of the double chloride is deposited, and can be operated upon again, as before. At the close of the process magnesium chloride will remain, almost alone, in the Mother-liquor, which will mark about 38° Beaumé.

The potassium chloride, obtained as indicated, is converted into potassium sulphate by sulphuric acid, and then into potassium carbonate by Leblanc's process, in the manner already described. This form of potassium carbonate is quite free from metallic impurities, and is in great demand for the manufacture of crystal and Bohemian glass. M. Balard calculates that the amount of potassium chloride is equal to one per cent. of the common salt in the brine—one ton to a hundred tons. As it is thirty times more valuable than bay salt, it is worth while extracting it.

If the evaporation of the Mother-liquor from 38° to 44° Beaumé is continued by artificial heat, the last dregs of the salts, above-mentioned, will separate, leaving magnesium chloride nearly pure. On removal of these salts the greater part of the liquid will, on cooling, solidify into a mass of hydrated magnesium chloride crystals. This chloride may be employed to furnish caustic, and carbonate of magnesia, by decomposition. When calcined in a current of steam, it is completely decomposed into hydrochloric acid and impure magnesia. Or, the Mother-liquor itself, if acted upon by steam, at a high temperature, will furnish these products.

Bischof (Chem. Geolog. 1, 13 also XXIV) found that silicate of lime in solution acts upon the sulphate and chloride of magnesium, converting them into calcium sulphate and chloride, and silicate of magnesium. In this way, magnesium

chloride may be completely decomposed with an excess of freshly precipitated silicate of lime, leaving calcium chloride in solution.

A certain amount of *final* Mother-liquor remains after the last operation, and this contains the bromides, which may be got in respectable quantity by distillation with sulphuric acid and black oxide of manganese, in proper proportions.

At the French Mediterranean salt works, formerly, these processes, which are commonly known as Balard's, were roughly carried out as follows. After the Mother-liquor had passed through the supplemental manufacture of impure salt for fish curing and soda works, and had reached 32° Beaumé, two methods of procedure were followed for the sake of obtaining the residual salts. In the first, the Mother-liquor was at once further evaporated to 37° B. This evaporation afforded a very impure deposit, composed of a mixture of the residual salts, in the following proportions :—

	Parts.
Sodium Chloride.........	30
Magnesium Sulphate...	10
Double Potassium and Magnesium Sulphate...	25
Potassium Chloride ...	5

If the evaporation was pushed a little further, a mixture of the double sulphate, common salt, potassium chloride, and magnesium chloride, was obtained. Successive refinings furnished about one-fourth of the whole deposit as a pure double magnesium and potassium sulphate. The first deposit gave its own weight of alum; the refined double sulphate gave two or three times as much. The remaining Mother-liquor gave a deposit of impure double sulphate, which was burnt in a furnace with charcoal and lime, to transform it into crude potash, and operated upon by lixiviation to get refined pearl ash, K_2CO_3. This substance was

very difficult to fuse, owing to the presence of magnesia, which requires a powerful heat; and the loss of potassium, by volatilization, sometimes amounted to 20 per cent.

By the second process, the Mother-liquor at 32° B. was drained off from the beds to under-ground reservoirs, and retained in store until winter should enable manufacture to be resumed. In winter, when frost set in, the Mother-liquor was pumped up and exposed on the crystallizing beds again, and it then gave, owing to the double decomposition before described, a copious deposit of hydrated sodium sulphate. This was gathered for use, and dehydrated in a furnace.

Mother-liquor, separately evaporated to 35° B., to which that left from the last operation was also added, was pumped up to the crystallizing beds, and exposed in six-inch-deep irrigations, as soon as the temperature reached + 5° C. or 41° F. It then deposited nearly the whole of its magnesium sulphate in a state of purity. The Mother-liquor left from this operation was drained off again to the covered reservoir, and stored until returning summer should continue the evaporation. In the summer, it was pumped up and re-evaporated. At this second evaporation a double chloride of potassium and magnesium with a little common salt was formed. Two refinings gave a salt containing 99 per cent. of potassium chloride. These chlorides treated with sulphuric acid furnished potassium carbonate.

These operations for the extraction of the residual salts from the brine only ceased on the French Coast when the discovery of large deposits of these same salts at Stassfurth, in Prussia, the gift of a former Triassic sea, reduced the price to the vanishing point of profit.

An enterprising French manufacturer, M. Merle, has pressed into the service of this branch of salt culture, Carré's

ice-machine, for the purpose of refrigerating the brine. His works are at La Camargue. His process is a development of M. Balard's, and he claims for it a great saving of time, and of Mother-liquor, which wastes a good deal in clay works. It is conducted as follows: First, brine is evaporated to 28° B. in the open air, and the common salt removed. Next the Mother-liquor is placed in covered tanks, and 10 per cent. of fresh water added to it, as it is a little too strong for the proper reaction. Then the resulting liquid is passed through refrigerators, which reduce it to—18° C., (about —4° F.) At this temperature sodium chloride and magnesium sulphate break up into sodium sulphate, which is deposited, and magnesium chloride, which remains in solution. The brine is made to circulate continuously through the refrigerator, in at one end, and out at the other; and sodium sulphate is withdrawn, as fast as it deposits, by an endless chain of buckets. The sulphate is first freed from Mother-liquor by a centrifugal hydro-extractor; and then dried in a reverberatory furnace. If the 10 per cent. of water were not added, much hydrated sodium chloride would form, and adulterate the sulphate; but the extra water keeps it in solution together with potassium and magnesium chloride. As soon as sodium sulphate ceases to form, the brine is passed into boilers, and boiled down to 36° B., by which means it is forced to deposit the remainder of its common salt. This salt forms a fine powder, which, when dried in a centrifugal machine, equals the best English table salt.

Potassium chloride is next dealt with. The remaining brine, marking 36° B., is poured into shallow concrete basins, where it cools and deposits all its potassium chloride, together with a double chloride of potassium and magnesium ($K. Mg. Cl._3$), or artificial *carnallite*.

From the latter, magnesium chloride is removed by the

addition to the mixed mass of half its weight of fresh water. About one-fourth of the potassium salt is, however, lost, passing off with the more soluble magnesium chloride. The potassium chloride so formed contains only 10 per cent. of extraneous matter. The magnesium and potassium chloride remaining in the brine is returned to the boiler. The potassium chloride is dried in the centrifugal machine. By this process M. Balard's tedious and complicated method is shortened and made more decisive. After refrigeration, not more than 12 or 15 per cent. of the original sulphuric acid remains in the brine. Very little potash falls with the common salt in the boiler. Owing to the separation of the sulphuric acid in the refrigerator, no crust forms in the boiler, as in ordinary salt boilers. A cubic metre of Mother-liquor yields by this treatment 40 kilos of anhydrous sodium sulphate, 120 kilos *refined* table salt, and 10 kilos potassium chloride. The remaining magnesium chloride can be operated upon by silicate of lime.

Besides the saving of wastage, this is a manufacture which can be conducted all the year round, almost independently of the weather.

The final Mother-liquor, after all these operations, marks about 44° B. It may be utilized by mixing it with ordinary saturated sea brine at 25° B, when nearly all the sea salt will be forced out in minute crystals, which can be washed free of magnesium, in strong brine.

CHAPTER XIII.

BRINE SPRINGS.

In the term brine springs, as here expressed, are included all geological sources of brine, together with the sea brine found in the subsoil on the sea shore.

To take the latter first. At many of the Coromandel salt stations, though they may be situated within a few hundred yards of the sea, or estuary, as the case may be, common salt is manufactured exclusively from subsoil brine. It is found that brine wells, sunk in the neighbourhood of the sea shore, often yield a much stronger brine than pure sea water. It is no uncommon thing, on the Coromandel Coast, to strike brine at a depth of from five to fifteen feet from the surface, having a density of from 6° to 12° Beaumé; even stronger brine, is sometimes met with. At Vedarnium, near Point Calimere, the subsoil brine has been known to reach saturation, 25° B.; but it is more usual to find it at about 6° or 7° Beaumé. Even at 7° B., however, it is twice the strength of sea water, and one-half of the work of evaporation is, as it were, accomplished in it.

The strata generally met with on the salt swamps of the Coast, reckoning from the surface, are sand, loam, clay, and silt. When sand is found at the surface *above sea level*, it usually contains fresh water. Indeed, many salt and fishing villages are built on the sand, and are entirely dependant for fresh water on surface wells, sunk to a depth

of five or six feet. When the sand is cut through, below the sea level, the water gets brackish, and finally good brine is reached at no great depth from the surface. In sand, it is generally weaker than in loam or silt; and when there is no surface drainage, but a strong undercurrent towards the sea, it is weak and abundant. When the subsoil is a rich shell marl, or estuary silt, brine is strong and plentiful.

It would appear that owing to the pressure of the sea on its loose shore, a considerable volume of water is forced to percolate inland; filtering through saline soil, probably old estuary deposits, it gains in strength as it proceeds, but falls away from the surface and diminishes in quantity, in the same proportion. It follows that the depth at which brine is obtained, its quantity and its density, the conditions of soil being the same, vary with the surface level and the distance from the sea; the further inland, the denser, the scantier and the deeper. The character of the soil, however, the proximity of rivers, and the nature of the subsoil drainage, influence the quality of the brine very much. In some cases the subsoil drainage, or the natural drainage of the country towards the sea, passes through silted up marine strata containing salt, and is saline; and such subsoil brine may even be found above the sea level. The author however, though he has examined the subsoil water at scores of places, scattered over 1,500 miles of coast, has never found brine, above the sea level. Still, it is to be noted, that it is derived from two sources, often in combination. Sea-formed subsoil brine has usually fresh water drainage associated with it, more or less, according to the character of the strata and surrounding circumstances. In the vicinity of rivers the subsoil brine is always very weak.

Brine pits, notwithstanding the initial strength of the brine they yield, are generally a very unsatisfactory source of brine supply for salt manufacture. In the first place, the brine is never sufficient for a large and continuous salt service. A single pit will seldom irrigate more than from one to two acres, and pits have consequently to be multiplied over the surface of the saltern. Hence, there is great waste of manufacturing surface, and also no small expenditure is incurred in making the pits. Again, the lift is high, generally from ten to fifteen feet, much higher than where sea water is employed. Pits, too, are put out of work when rain occurs as they serve as catch basins and receive the surface drainage from the neighbouring ground. When thus freshened, they cannot be used, as the fresh water remains at the surface of the brine, and takes a long time to evaporate. It is a suggestive fact that as the salt season, which is also the season of drought and hot weather in India, advances, the brine gets scantier and more condensed, from day to day, and the salt labourer has, in the end, to enlarge and deepen his pit, to keep up the brine service of his pans. This may mean that increased evaporation from the surface, increased work at the pans, capillary attraction, and absorption by the surrounding parched soil, have combined to dissipate the amount of brine pressed from the sea; but it also looks as if land drainage, which is getting scarce about this time, has much to do with the volume of subsoil brine.

Below the subsoil brine, at a variable depth, the percolated drainage from the interior of the country, passing out through deep strata, is sometimes met with. This has been tapped on the Coromandel and on the Mediterranean Coasts, by means of deep artesian wells, which supply fresh water. It appears, therefore, that on loose swampy shores, there is

above the sea-level, fresh water drainage towards the sea, which may be rendered saline by passing through old silted up estuaries. Below the sea level, for some few feet, brine is met with, which diminishes rapidly with distance from the sea, and is scarcely perceptible a mile inland. The salinity of this stratum seems to be caused by the filtration of sea water inland, due to the hydrostatic pressure of the sea, wind-waves, and tides. The connection of the brine in the subsoil, with the sea, is proved by the fact that it has been often noticed to ebb and flow with the tide. I have elsewhere drawn attention to this fact, and Dr. Brownrigg states that he has observed the same thing in pits near the sea.

Pit brine is suspected of containing a larger percentage of foreign salts than sea water. The following is an analysis of pit brine from Negapatam, in the neighbourhood of which town, are large and important subsoil brine salterns.

Sodium chloride	7·434
Magnesium "	1·020
Magnesium sulphate	·615
Calcium "	·408
Water	90·523
	100,000

Analyst—W. Macrae, M.A., M.B.

This analysis seems to show that subsoil brine is less pure than sea water. Compared with the analysis of the adjoining Bay of Bengal, given at page 65, the sodium chloride is not multiplied quite three times, whereas the other salts, and especially magnesium chloride, the most obnoxious, are multiplied very nearly four times. The pit from which the

brine was taken was situated about half a mile from the Bay of Bengal. Whether, or not, this analysis fairly represents the state of pit brine at other parts of the same coast, is uncertain; but the conditions of soil, etc., are in most cases the same, and it is at least probable that in addition to the more obvious objections to the exclusive use of pit brine, in salt manufacture, its impurity may be added. The excess of magnesium salts may also be accounted for by the operation of salt manufactories, which extract common salt and allow magnesium to accumulate in the soil. In any case, however, it will be understood from what has been written about salt culture, that a very pure salt may be made, with skill and knowledge, from a very impure brine.

Pits are made with wide sloping banks, to avoid land slips. Where brine is found in good substantial silt, or trickling through thin seams of sand, or shell marl, pits stand well enough. But where, after digging through clay, large masses of thin silt, or sand, are found, yielding subsoil brine, pits are soon undermined, and collapse. In such formations, wells are sunk, and their walls are supported by means of twisted twigs and branches woven round together, as an inside lining.

Salt is manufactured from pits in almost precisely the same way as from sea water. But as pit brine is already much stronger than sea water, less trouble is taken to condense it, before passing it into the crystallizing beds.

The Madras Salt Commission of 1876, summarize their opinions as to the effect of the source of brine supply on the composition of pit salt in the following paras :—

" We have, therefore, in the following tables grouped the analyses of the forty-one platform specimens according to the source of brine supply, and shown the composition of the average salt of each group."

Table of Salt Analyses.

	Source of Salt Manufacture.					
	Sea water, average of 9 specimens.	Pit brine, average of 9 specimens.	Sea and pit brine, average of 3 specimens.	Backwater, average of 19 specimens.	Backwater and pit brine, 1 specimen.	All sources, average of 41 specimens.
Sodium chloride ...	86·137	82·557	83·884	85·554	83·168	84·839
Magnesium „ ...	2·005	2·390	2·919	2·156	2·294	2·233
Calcium „ ...	0·438	0·229	...	0·084	...	0·185
Magnesium sulphate	0·416	0·198	0·525	0·565	0·181	0·399
Calcium sulphate ...	1·610	1·553	1·374	1·216	1·366	1·315
Organic matter ...	0·122	0·229	0·063	0·133	0·521	0·156
Insoluble inorganic residue..............	1·364	2·472	0·580	1·746	1·497	1·730
Water..................	8·675	10·534	11·049	8·615	10·811	9·281
	100·767	100·162	100·394	100·069	99·838	100·138
Total impurities other than water...	5·955	7·071	5·461	5·900	5·859	6·018
Total of all impurities	14·630	17·605	16·510	14·515	16·670	15·299

Analyst—Dr. Hazlett, Madras Army.

"The percentage of moisture is lowest in the salt from backwater brine, but no definite conclusion can be based on this result. The specimens made from mixed sea water and pit brine show the best average in respect of freedom from insoluble impurities both organic and inorganic, and if we set aside the single specimen from Cheyur, the salt from pits is worst in both these regards. Salt made from pit brine, or partly from pit brine, and partly from sea water, shows an excess over the other salts in the percentage of magnesium chloride, and the salt from pit brine alone stands

at the bottom of the list, whether in respect to percentage of solid impurities or of all impurities, moisture included. The salt made from sea water and pit brine, shows best in respect to freedom from solid impurities."

The table of analyses, prepared by the Madras Salt Commission, classifies a large number of salt samples according to their origin, whether from sea water, pit brine, etc. It shows that as regards the more important impurities which salt manufacture habitually produces, there is very little difference in results, no matter what class of brine is used in the process. For example, to take magnesium chloride, the most pernicious of the impurities referred to, all the sample averages show more than 2 and less than 3 per cent. of that salt. Sea salt shows 2·005 per cent.; pit brine salt shows 2·390 per cent.; and curiously enough, salt made from a combination of both sea water and pit brine, shows 2·919 per cent. magnesium chloride. The other residual salts appear to be contained uniformly throughout the series tested. The chief difference resides in the items, inorganic insoluble residue, commonly called dirt, and water; and as the samples were not all of the same age or manufacture, the source of brine supply cannot be held responsible for the differences of dirt and moisture found in the specimens. The practical result of a study of this valuable table, is, that when the right conditions of manufacture are fairly observed, the source of brine supply, within the limits given, has surprisingly little influence on the composition of the resulting salt.

Brine springs.—Apart from the brine sources, already noticed, which have their origin in the sea, brine springs are very numerously scattered over the face globe, especially in situations in which rock-salt formations are known to exist. The list of medicinal brine springs, furnished at page 143,

and the Cheshire brine springs, illustrate, this point. Indeed there can be very little doubt that all brine springs of any extent, which are not directly supplied from the sea, owe their salinity to contact with a rock-salt formation, in some part of their course. This is a proposition generally admitted. T. Sterry Hunt, however, seems to hold that the porous Silurian rocks of Canada, which yield brine, retain, as in a sponge, the water of the palæozoic sea. This startling theory rests on the fact that these springs are rich in calcium chloride, a salt characteristic of the palæozoic sea. He gives the following analyses; the first of a copious spring which issues from the Trenton limestone, at Whitby, Ontario; and the second from a boring, sunk 500 feet deep, through sandstone, into underlying shales, at St. Catherine, Ontario. 1st. Sodium chloride, 18·915 parts; calcium chloride, 17·531; magnesium chloride, 9·543; sodium bromide, ·248; calcium carbonate, ·041; and magnesium carbonate, ·022, per thousand. 2nd. Sodium chloride, 29·803 parts; calcium chloride, 14·854; magnesium chloride, 3·397; calcium sulphate, 2·192; and potassium chloride, ·355 per thousand. A water at Bras d'Or, in the Island of Cape Breton, also contains 4·901 sodium, and 4·413 calcium chloride, in combination with the usual residual salts of the sea.

The presence of large quantities of calcium chloride in brine springs is very curious and interesting; but it is a long stretch of ages to the palæozoic sea; and what solution, freely exposed, could survive the intervening time without chemical change? We have seen that common salt and lime, under certain conditions, form sodium carbonate and calcium chloride, and that calcium chloride sinks deep into the ground, whilst sodium carbonate effloresces and is washed off. These conditions may have existed at one time, perhaps exist still, in or about the Trenton limestone, or in the earth above it,

giving rise to the formation of calcium chloride in large quantities.

It is said also that some very weak brine springs take up salt from impermeable strata other than rock-salt, as at the Alleghanny mountain springs, which hold, in a hundred parts, 3·200 sodium chloride, ·038 *barium chloride*, ·568 calcium chloride, and ·293 magnesium chloride. The presence of barium chloride in a solution shows that it could not have come in contact with a soluble sulphate, for it would have been precipitated as barium sulphate if it had. According to Lenny, the presence of barium and strontium chlorides, and the consequent absence of sulphates, is a constant character over the whole of the Allieghanny river valley region; from whence brine is obtained by boring in the coal formation. But this, after all, may be due to the purity of the rock-salt which furnishes the brine. Magnesium sulphate is not found in the table of the analyses of rock-salt given at page 116; and no sulphates of any kind are found in the rock-salt of Wielizcka, Holstein U. S., and Ouled, in Algeria. There are no sulphates in the 1st Ontario brine spring, above described. It may well happen therefore, that brine springs containing barium arise from rock salt formations free from sulphates.

Near the town of Onandaga in the north of New York State, and about 300 miles from the Atlantic, some copious salt springs are at work, which yield the celebrated Onandaga salt. At the northern sources of the Arkansas river, too, salt springs are found, diffused in the soil. In Kentucky, similar salt swamps exist; and the bodies of mastodons and elephants have been unearthed in the neighbourhood. Sir C. Lyell supposes that at the period when these animals resorted to the salt springs, extensive quagmires existed, into which they were forced by the on-

rush of hordes of allied beasts, repairing to the springs and saltlicks. At Gallatin, in Illinois, salt springs are very numerous, and give rise to a considerable salt manufacture. At the Big Muddy saline, in Illinois, one spring which rises from a depth of 200 feet, throws a jet of brine, six feet high, above ground level. These springs are reached by means of narrow jumper borings, formed with tedious labour. Norton's tube wells would seem to be well adapted for such work. Nearly saturated brine is found in the Saginaw valley, Michigan.

The Onandaga rock salt supplies the strong brine of Syracuse and Salina, in the state of New York. These springs contain 14 to 16 per cent. solids, averaging, 1·54 calcium sulphate, 0·93 calcium chloride, 0·88 magnesium chloride, and the rest, 10 to 12 per cent., common salt.

Most of the American salt is made by the evaporation of brine obtained from springs. At Salina and Syracuse the salt is made in two ways; on the block systems and, by solar works. The block system is worked as follows. From 16 to 40 potash kettles, holding about 100 gallons each, are set in a long masonry tunnel of horse shoe-shape, having fires at the open ends and a factory chimney in the centre to create a draught. In the pots the brine is simply boiled down for salt.

Solar works.—First the brine is stored in reservoirs; then it is brought to wooden vats, resting on posts, 18 to 36 inches high, which admit of the vats being levelled, in spite of surface inequalities. These vats are 80 to 640 feet long, 18½ feet wide, and from 6 to 15 inches in depth. They have roofs in divisions of 16 feet each, mounted on rollers, which travel on level supporters, and which can be moved on and off by the strength of one man. These are depositing vats; the brine remains in them until it reaches about

12° B. It is then passed on to other wooden vats, at a lower level, where it is kept at a depth of six inches until nearly saturated. Then the brine is passed into still lower vats, *kept clean*, where the salt forms in about five inches of brine; the depth being maintained by fresh supplies of brine. From these vats the salt is either scraped up frequently, or allowed to cake, according to fancy. In either case it is put into tubs, holding about 100 lbs., drained for a few minutes, and then carted to store. It is estimated that the Solar establishment at Syracuse occupies 110 acres, including reservoirs, paths, and vats; that the wooden vats occupy 1,250,000 square feet; and that the annual produce is 3,500 tons of salt. Wood was formerly plentiful in those parts.

On the borders of Thibet, in the Chinese province of Szu Zchouan, salt springs occur, associated with springs of inflammable gas. These springs are very numerous on the east side of the mountain chain which runs north and south, through the province. M. Imbert states, that there are some thousands of salt springs, in a space of ten leagues by five, near the town of Ou Thouang Khiao. These springs are bored into, with great labour and perseverance, with very imperfect machinery; and the Chinese, with wonderful tenacity of purpose, continue the borings to remarkable depths. The wells pay very handsomely, however, as the brine itself is not far from saturation, containing from 20 to 25 per cent. of sodium chloride; and it is quite usual for a single spring to yield not only the brine, but also sufficient inflammable gas to procure its evaporation by boiling. The brine is boiled off, in shallow cast iron vessels, to which the inflammable gas is conveyed in bamboo tubes, terminating in fire clay pipes. In boring for these springs, a bituminous oil is sometimes met with, and coal formations are also struck.

In the interior of the Island of Java, in a limestone district, hot saline springs occur, which are supposed to be of volcanic origin. The springs are numerous, and are spread over a tract several miles in circumference. Many of them are thrown up to the surface with considerable force and ebullition. They make such loud noises and give rise to so much steam, that they attract attention a long way off. The springs are strong and yield good salt. Dr. Horsfield describes one such spring, or group of springs, nearly half a mile in circumference, which cast up, at intervals of five seconds, a great globe of brine and earth, which burst with a loud report and the formation of thick clouds of vapour. The brine from the spring was conducted by means of earthen channels, to shallow evaporating pans at the circumference of the disturbed circle, and there manufactured into salt. (*Raffles' History of Java*, vol. i.)

The great salt deposit of Lake Inder, near the town of Uralsk, in the Asiatic steppes of Russia, which has been already noticed, seems to be formed entirely from brine springs, the orifices of several of which appear in the salt formation.

The Barbary States and Algeria, in the north of Africa, are plentifully supplied with brine springs.

A very interesting coal and salt spring region exists at Deluj-Tuzla, in Bosnia.

At Zipaquera, in New Granada, salt is manufactured from brine springs, although rock-salt is exposed, in seams, in the mountain above the town; but this salt is so impure that it is only fit to strengthen the spring brine. Salt manufacture is a Government monopoly, and is rented by a Company. The strong spring brine, averaging 18° B in density, is let into basins of substantial masonry, coated with cement, in which rock-salt is put to help to saturate

the brine. When saturated, the brine is evaporated for salt, which is then gathered and removed to a furnace to be melted. This is the peculiar feature of Zipaquera manufacture. The furnace is an arch, or dome, built up of unburnt clay-bricks, and earthen pots, jammed together, and supported in a great measure by firewood, with which the interior is stuffed. There are about 150 pots to each furnace. When the fire is lighted, smoke, at first, escapes through little holes made in the clay between the pots; but these are closed up after four or five hours. As soon as the heat is great enough, a little saturated brine is thrown into the pots as a glaze, then salt is put in, till the pots are full. For the first 24 hours of baking, saturated brine is thrown into the pots occasionally to consolidate and unite the granular salt: and for 48 hours more—altogether for 72 hours—the fire is kept burning brightly. The furnace is then allowed to cool, and when cooled, is filled up with fresh firewood, to support the dome when broken up, and to help in building a new one afterwards. The arch is then broken, pots included, and the pots are handed over to women who chip off the earthenware from the solid salt with chisels and mallets. The salt now forms heavy rounded masses, having the look and feel of marble, and so glazed that they resist rain, and are carried without loss, through rivers, on the backs of mules. As an illustration of "salt prejudice," which is often amazingly strong, it may be mentioned that the Zipaquera Company at one time stopped the manufacture of this expensive solid salt, and tried to sell granular salt at a much cheaper rate. The result was their sales fell off remarkably. The natives would not use the granular salt. They discovered that it made them ill, etc.; so the Company had to go back to their furnaces and fire balls again!

In the north of India, along the borders of the mountain range, known as the salt range, salt springs are of common occurrence.

Brine springs are also found at the foot of the hills, in the Trans Indus salt range. Mr. Wynne, of the Geological Survey, remarks on the frequent presence of large pot hole craters in the salt deposit, and states that this denotes special areas of salt solution and the existence of underground currents which issue as brine springs. He also notices "streams disappearing subterraneously into dark caves in the salt, to find an exit, no person can tell where." In Australia where no rock-salt has, as yet, been discovered, Franklin found rivers as salt as the sea, emptying themselves into the Mackenzie river. There is very little doubt that many of the salt springs of Cheshire are formed by the river Weaver, flowing into abandoned salt mines, or scooping out a channel for itself in the bed of rock-salt.

As strong brine is heavier than weak brine, and diffusion makes little progress as a general rule, the density of brine springs increases with the depth of the boring. This is well shown by the following observations taken during the boring at the Dunenberg Salt Works.

Depth.		Sodium Chloride.
At 37·6	feet, the brine contained	4·38 per cent.
55·0	,, ,, ,,	3·79
74·5		2·95
91·0		3·21
280·0		4·64
285·0		3·82
305·0		4·94
463·0		2·50
502·0		2·90
588·0		4·25
706·0		3·30
815·0		5·25
965·0		6·82

Depth.		Sodium Chloride.	
986·0 feet,	the brine contained	9·26	per cent.
994·0 ,,	,, ,,	12·14	
1024·0		17·00	
1026·6		19·16	
1028·5		17·06	
1055·0		16·86	
1064·0		16·57	
1133·0		15·15	
1138·5		14·08	
1158·0		14·66	

Alterations of strength may be accounted for by supposing that the various plains of stratification bored through are traversed by brine solutions of different densities, according to their surface of contact with rock-salt, and abundance of fresh water. Occasionally the boring may go below the rock-salt level and tap streams of fresh water.

The salt works at Prussian Minden are supplied by a boring, which passes through the new red sandstone into the Muschelkalk, to a depth of about 3,000 feet from the surface.

Borings directed with a view to tap the sources of natural springs, at some considerable distance from their natural outlets, are often successful in obtaining a stronger brine. Thus at Rodenberg, a spring containing 0·6 per cent. of sodium chloride at its natural outlet, was found by judicious boring near its source, to yield brine holding in solution 5·1 per cent. of salt. Test borings, of the nature described, should always be undertaken under the guidance and direction of a practical Geologist, otherwise a good deal of money may be thrown away in useless labour. In many cases the brine, as in artesian wells, is forced to the surface by hydraulic pressure.

In Cheshire, brine is obtained by sinking shafts near the banks of the Weaver, and also of the Wheelock, a smaller

stream. It is found at depths ranging from ten to fifty yards, but the lower springs when tapped, generally rise to within a few yards of the surface. At Nantwich, brine is found at about ten yards from the surface. At Bampton, it is necessary to sink below fifty yards to reach it. In sinking shafts for brine pits, in Cheshire, fresh water-bearing strata are often cut through, and as a consequence, operations have to be suspended, or steam engines used to pump out the fresh water. Sometimes, a smaller shaft is formed within the original shaft, and the space between is puddled with clay, to keep fresh water from mixing with the brine spring. Of late cast iron cylinders, in sections, with India rubber joints, are rapidly forced down, and the space between the cylinder and the walls of the shaft is filled up with cement. But these expedients often fail to keep out fresh water, and in such cases it is necessary to break fresh ground. When a spring is tapped, the brine is pumped up from its lowest limit, by means of tubes, so as to get at the strongest and heaviest brine, at the bottom.

Many of the brine springs of Cheshire are saturated solutions of common salt, which can be drawn off from the surface and passed into the graining houses, without further trouble. Such are the Marston and Wheelock springs, analyses of which are given below :—

	Solids in 100 parts.	
	Marston.	Wheelock.
Sodium chloride	25·222	25·333
Calcium sulphate	0·391	0·418
Magnesium carbonate	0·107	0·107
Sodium bromide	0·011	0·020
Sodium sulphate	0·146	....
Sodium carbonate	0·036	....
Calcium carbonate		0·052
Magnesium chloride		0·171

It will be noticed that the Marston spring contains no

magnesium chloride; whereas the Wheelock spring contains about half as much as sea water. These springs are obtained 40 yards from the surface.

The brine at Stoke is a little stronger in common salt, containing 25·492 in 100 parts. Freidricshall and Hall are stronger again, containing respectively 25·563 and 27·717 per cent. of salt.

At Birtley, in Durham, a salt spring occurs in the coal formation, which has the following composition, according to Mr. Winch (Geological Transactions, vol. iv.)

Sodium chloride	87
Calcium ,,	43
Magnesium ,,	4
Calcium carbonate, Ferrous ,,	4
Water	866
	1,000

About 2,000,000 tons of salt are made annually in England at the present day, chiefly from the Cheshire brine springs. The manufacture gives direct employment to about 6,000 people. At least 500 vessels are engaged in the salt trade; and 30,000 people, more or less, depend upon it for a livelihood.

Cheshire Salt Manufacture.—Brine is pumped up to the evaporating pans by steam. In former days, the brine was raised by hand-power, but as the works progressed in magnitude and importance, first, water wheels, then horse-power, then windmills, were used for this purpose, until, finally, steam pumps superseded all others. The brine is evaporated, or rather boiled, in large, iron boiling pans, about 60 feet long, by 40 feet broad, and 2 feet deep, resting on brick arches, beneath which furnaces and flues are arranged. It is remarkable that in some works the boiling pans are

exposed to the rain without any covering whatever; whilst, in the majority, a sort of pent roof surrounds the pans, leaving the centre open to the sky. This is perhaps to get rid of the steam, which is so great during the boil, that the enclosure is filled with thick clouds, rendering vision extremely difficult. It is found that this steam contains minute particles of salt, which no doubt is the cause of its great opacity.

The different varieties of Cheshire salt, as *stoved, common, large grained,* and *fishery* salt, are produced by modifications of the boiling arrangements.

Stoved Salt.—For stoved, or fine salt, the boiling pans are about three-quarters filled, and the temperature is raised to 225° F. The brine is then boiled down for about twelve hours, until it has lost about three-fourths of its volume, when the salt is raked up to the sides of the pan, and shovelled into conical baskets. These baskets are placed on ranges of pierced benches, along the walls of the boiling houses, and allowed to drain.

At some works the "fine" salt boilers are kept going continuously; the brine being supplied from time to time, as salt is scraped. Salt is scraped as often as sufficient forms to occupy the men. No baskets are used; but the salt is shovelled into wooden boxes, stirred up, and packed tight, with a wooden rolling pin. It is left in the box in the boiling room for two hours, to drain, before being turned out. If placed at once in *the drying room,* the salt will turn out of the box, solid, in ten minutes; but it is found that the brine draining from it, glues it to the floor so tightly that the force required to remove it, breaks it. There are two or three sized boxes, furnishing salt loaves of different weights. The salt is turned out of the boxes in the drying room, which is heated to 130° F., by rows of brick flues

connected with the furnace. Here *evaporation* takes place from the loaf, and new crystals forming, bind its particles together and compact it into a solid mass. This brick formation is the result of artificial heat and fineness of salt grain. In the drying room, the bricks of salt sometimes stick to the floor and have to be sawn off. These pans are cleaned out once a week, on account of the scale which forms on them, and wastes heat. No attention is paid to magnesium chloride, as it is small in quantity, and there is always sufficient brine to keep it in solution.

M. Patera has patented a method of making solid salt, which is applied in Germany. He drains the salt drawn from the pans and presses it in a vessel of enamelled sheet iron, in which it is exposed for 15 minutes to a temperatures of 150° C. = 302° F. It is then turned out, and dried in the air in the form of bricks.

Common Salt.—Common Cheshire salt is allowed to crystallize for twenty-four hours. The brine is raised to the boiling point, as for stoved salt, but then the fires are so damped, and managed, as to keep its temperature at 160° or 170° F. This salt, after draining in conical baskets, is stored at once, without exposure to artificial heat. This salt is about the size of the snow, or wind, salt, found at the lee side of bay salt pans. It is used for manufacturing purposes. It will not form bricks, being too large grained. The common salt boilers are not emptied much oftener than once in six months, as the pan scale is easily removed by scraping under the brine. The brine is maintained at a constant level of about 18 inches, by an automatic arrangement of brine pump. There is an intervening variety of salt, called "cheese salt," remarkably like fine snow, used for cheese curing.

Large.—Large grained salt is made at a temperature of about 140° F., and is allowed to crystallize for forty-eight

hours. As this salt is often crystallized during Sundays, it is known also as Sunday Salt. *Fishery Salt,* the coarsest description made, resembles sea salt very closely. It is formed from brine, evaporated at a temperature of about 100° F., and consequently its formation occupies a period of five or six days.

During the boiling process, it often happens when the brine is inferior, especially if carbonates are present, that a scum forms on the surface. Sometimes glue or waste grease is added to assist in forming the scum, which is then removed by skimming. At other times, the scum rapidly subsides and requires to be raked out early in the process. This subsided scum, or "*cleanings*" as it is locally called, Dr. Henry found, had the following composition in 480 parts:—

Sodium chloride	384
Calcium sulphate	76
„ carbonate	20

This scum forms a slab on the bottom of the pans, an inch thick. I found heaps of pieces thrown into the gullies to dissolve and waste. Pieces that I took home were very pure; they dissolved in fresh water, leaving only a trace of insoluble calcium residue. It is a pity to see it wasted, as it would grind down into fine salt. The slabs resemble marble, and are as hard as stone; but they show lines of stratification along their edges. Marine salt slabs moisten and effloresce along these lines, owing to the presence of magnesium chloride; but the Cheshire slabs remain dry.

Formerly a variety of "seasonings," as the workmen called them, were used to purify the brine, as wheat flour, resin, butter, tallow, wine lees, new ale, stale ale, alum, albumen, blood, and whey kept for several years. The use of the latter ingredient was supposed to be the secret of the superiority of Dutch salt, 200 years ago. These substances may

be divided into two classes: 1. Those added to remove solid impurities as dirt of all kinds, and which coagulate by heat, as blood, albumen, and glue. 2. Those which prevent pellicle formation, as oil, butter, alum, and resin. A few grains of resin are said to have a magical effect. The use of alum is carried a little too far in some places, as I have seen alum crystals bristling over lumps of fishery salt.

The bottoms of the boilers, also, in course of time, get covered with a thick stony deposit, which the workmen call *pan scratch*, or *pan scale*. This scale has to be removed at least once a month with pickaxes. It is composed mainly of calcium sulphate, which falling to the bottom of the pan and being covered with other deposits, is in time very likely overheated, during the boiling, and converted into *anhydrous*. The latter re-absorbing moisture, sets, and cements the contiguous salts into a solid scale. Dr. Henry found the composition of the pan scratch to be as follows, in 480 parts:—

Calcium sulphate	380
" carbonate	60
Sodium chloride	40

Scale forms chiefly on the bottom of the *fine* salt boilers, in which saturated brine boils at a high temperature, discharging large bubbles of steam. Karsten found that the boiling temperature of supersaturated brine was 108° ·83° C or 276° ·86 F. But at 275° F. calcium sulphate, or gypsum, abandons its water of crystallization and forms "anhydrite." Considering the density of the brine, it is strange that calcium sulphate is found at all in it. We have seen that, according to Berthier, it is not soluble in brine containing 22 per cent. of sodium chloride; but this brine contains, according to the analyses given, (taken from Tomlinson's Dictionary,) more than 25 per cent. of salt. Perhaps Berthier refers exclusively

to sea brine, containing much magnesium chloride. However, even in Cheshire, the sulphate must be nearly supersaturated, if not held in mechanical suspension. The obvious way to get rid of it, to the mind of a bay salt manufacturer, would be to evaporate at first at a low temperature, above or below 110° F., at which point calcium sulphate attains its maximum of solubility, and thus get rid of the sulphate. The first appearance of salt in the pan might be taken as an indication that all the gypsum had deposited, as it would naturally be forced out before the more soluble sodium chloride. The sulphate might then be easily removed; and the brine boiled at a high temperature for "fine" salt. Or, brine from the common, or fishery salt pans, which had *parted with its gypsum,* might be run into the fine boiler, and boiled down without fear of scale, the supply being kept up from the other pans. Again, carbonate of soda, added to the brine, changes lime sulphate into sodium sulphate and lime carbonate, which latter does much less harm to the boilers, and is comparatively easily removed.

It sometimes happens that rock-salt found in the neighbourhood is freer from calcium sulphate than spring brine, and in that case it pays to dissolve and refine it; but at Wheelock, the proportion in both cases is about the same.

Good sea salt is free from calcium sulphate, and may be refined by boiling without the formation of pan scale, a decided advantage. I examined the boilers at Croisic, and found that they are quite free from scale.

Many improvements have been attempted in the manufacture of Cheshire salt, as described, and various are the patents which have been taken out for this purpose; but, so far, no real substantial alterations have been established in the process. Some patents are chemical in principle, and aim at getting out the sodium chloride by the addition of other

more soluble salts, such as calcium chloride, magnesium chloride, etc., but these salts appear as impurities in the products, and necessitate further processes for their removal. By far the larger number of patents are directed to economising fuel, or saving the wear and tear of the evaporating boilers. These are briefly enumerated and described by Watt's (Chem. Tech.) as follows:—

"Some of the patents modify the number, shape, and setting of the pans; or convey the fresh brine to the pans through pipes warmed by the waste heat of the furnaces; or employ hot air or steam in pipes immersed in the brine; or force hot air through or over the brine; or expose the brine, in thin films or spray, to the action of the heated gases from furnaces; or subject the brine, in fibrous or other materials, to the action of currents of heated air; or conduct the evaporation in closed pans, and employ the steam from the brine, for heating a second set of pans filled with brine of a lower specific gravity; others create an artificial draught, to carry off the steam more rapidly from the surface of the brine as it boils."

"There is one plan in operation, which consists in dissolving rock salt in sea water, and either evaporating the liquor by the waste heat of a lime kiln, or in the ordinary manner, by fires underneath the pans, and making use of the waste heat to dry levigated chalk, which is used for whitening."

"As regards saving the wear and tear of the pans, some of the proposals consist in arching the bottom of the pans over the furnace; others employ revolving pans, which never remain long exposed to the direct action of the fire; others deepen the farther end of the pan to receive the salt; others employ coolers, or construct the pans with sides extending beyond the furnace, where the salt may deposit; and others substitute inverted cones into which the salt may fall; the

object in each case being to prevent the deposit of salt on that part of the pan bottom directly over the fire; in other patents, the salt is constantly removed, by a mechanical arrangement of scrapers or rakes, into pockets at the sides of the pans; or the pans are constructed with double bottoms and sides, the intermediate space being filled with water heated by the ordinary furnaces; and in one case the exposed part of the pan is covered by a fusible alloy, to which the pan-scratch attaches itself, and from which it is easily removed."

"In some patents, both objects are attempted, by a combination of one or more of the plans we have thus briefly indicated, but we are not aware that any of the numerous suggestions have been carried into constant and daily practice." Formerly, in Germany, salt manufacturers used zinc plates to protect the iron joints of their boilers, but they found that the zinc was attacked by the brine, and crystallized as a double chloride of sodium and zinc, which adulterated the salt. They were therefore obliged to give up zinc, as its salts are all more or less poisonous. A large number of new patents are noticed in the "Scientific American."

Owing to the complete absence of free oxygen from boiled brine, no rust forms on the inside of the boilers, below the brine level. But the top edges and the outside are attacked vigorously by the salt atmosphere, since salt helps the oxygenation of iron. I have seen the edges of old boilers toothed like a comb.

Salt manufacture, on the continent of Europe, is often carried out at a disadvantage, owing to the weakness of the brine. In some places, as at Wimpfen, where the boring passes into solid rock-salt, fresh water is let down to dissolve the salt, and afterwards pumped up again as a saturated solution. In parts of Cheshire, on the other hand, the weak

brine from springs is strengthened by the addition of impure rock-salt, which is dissolved in it before it is evaporated at the pans. In this way, a nearly saturated brine is obtained, which is evaporated by artificial heat.

At many places, owing to the scarcity and price of fuel, various contrivances are had recourse to, to assist natural evaporation. At Moutiers, on the Isere, in Savoy, the brine is allowed to trickle through bundles of twigs, or is made to traverse festoons of ropes, with a view to expose the largest possible surface, and for the longest time possible, to atmospheric evaporation.

The springs from which the Moutiers salt is made are hot springs, in the valley of the Doron. The temperature of the brine is about 99° F.; and the vapour it gives off consists in great part of a mixture of hydrogen sulphide and carbonic acid gas. The brine contains from 1·83 to 1·50 per cent. of sodium chloride, together with the ordinary residual salts, in small proportions. It contains, besides, a small quantity of oxide of iron. The brine is brought in a channel from the springs to a large collecting reservoir, in which it deposits matters in suspension; it is then passed on to the pumping-house, from which it is pumped up to the top of the *Maison des Epines*, or thorn-house—or Maison des Cordes, or rope-house—as the case may be. The pumps are worked by water wheels, driven by a small aqueduct from the river Doron.

Thorn-houses.—There are four thorn-houses. The first two are each 350 yards long, the third, 370 yards, and the fourth, 70 yards in length. These houses are merely long wooden frame works, not unlike the open frame work of an iron girder, but covered with a raised pent-roof, and resting on stone buttresses. The interior of the frame work is filled up with loose bundles of twigs, placed transversely

and sufficiently apart to admit of the free circulation of air. The thorn-houses, it should be noted, are only 7 yards broad. The brine is pumped up to a central tower, from whence it is distributed to two channels, running the whole length of the thorn-house. From these channels it flows into smaller perforated channels, which drop it in a gentle shower on to the twigs, close to their free ends. It trickles slowly through the twigs to another channel at the bottom, whence it flows into a receiver, and is pumped up again if necessary, for a second fall. Ordinarily speaking, one fall raises the spring brine one degree in density; but in damp or calm weather, it may require a second, or a third fall. From the first house the brine is taken to the second, and pumped up and distributed as before. In the second house, it is treated until it contains 3 per cent. of salt; *i.e.*, until its volume is reduced to one-half. From this it is taken to the third house, in which it is evaporated until the percentage of salt reaches 12; and, finally, it is evaporated in the fourth house, until it is nearly saturated. The saturated brine is then boiled in boiling houses, and the salt collected in much the same way as in Cheshire. By means of those thorn-houses an immense saving of fuel is effected. Thus 1,000 parts of brine are reduced to 500 in the first and second houses, to about 125 in the third house, and, in favourable weather, to about 68 in the fourth house.

By an arrangement of sluice gates, the brine in the upper channels can be shut off from one side of the twigs and made to fall exclusively on the other; and, except in the first house, in which the brine is comparatively weak and valueless, this is generally done, so as to expose the falling brine only on the windy side. The houses, too, are built so as to expose their sides to the prevailing winds.

The twigs are changed in the different houses at varying

periods. Those in the last house are preserved longest by the antiseptic action of the saturated brine, and are changed every seven years. Those in the first two houses require to be removed every four or five years. Those in the third house are preserved, though at the same time their efficiency is impaired, by a thick deposit of calcium sulphate, which gives them the appearance of branching coral. It does not appear that any of the twigs undergo petrifaction.

Rope-houses.—Formerly, in the summer months, the brine from the thorn-houses was conducted to the rope-houses, and the salt was extracted by natural evaporation, and crystallized on the ropes; now, fir fuel, or anthracite, is generally used, and the brine is boiled for crystallization. The ropes are still used, however, in the later stages of condensation. Brine is evaporated quicker by ropes, than by thorn-houses, and when strong brine only is used, the ropes last for a very long time—it is said for thirty years. Most of those at Moutiers are so incrusted with gypsum that the brine cannot touch them. Originally of a thickness of a finger, many of the ropes have grown with gypsum incrustations to ten times that size.

The rope-houses are built on stone arches, roofed in, and are much stronger than the thorn-houses. They are about 77 yards long, 11 wide, and open to the air at the sides. The entire length of rope is about 115,000 yards. It is arranged in separate sections, in vertical rows, to catch the wind. The cords are double, each about 32 feet long, and are tightly wound over two horizontal bars, one above, the other near the ground, 16 feet apart, so that the height of each framework of ropes is 16 feet. The brine is pumped up to channels running above the ropes, and so perforated as to drop continuously on each double piece. Formerly, as soon as a cylinder of salt, 2½ inches thick, formed on the rope, it was broken off, and gathered from the floor.

The rope salt was always very pure. The salt formed by boiling is of three varieties, according as it is gathered early in the process, or towards the middle, or at the close of crystallization. M. Berthier analysed these salts with the following results :—

	Sodium chloride.	Magnesium chloride.	Magnesium sulphate.	Sodium sulphate.	Calcium sulphate.
1st	94·64	......	......	3·80	1·56
2nd	93·59	0·61	0 25	5·55	......
3rd	85·5	2·0	12·5	......	......

Graduation.—Many of the German salt springs being too dilute to pay the expenses of artificial boiling, the brine is treated in thorn-houses, as at Moutiers, before being boiled. The German process is scaled graduation. It is almost exactly the same as that described in connection with thorn-houses.

At Schönebeck, it is necessary to evaporate 19 million cubic feet of brine to get 28,750 tons of salt.

The thorn surface employed in evaporating the brine amounts to 390,000 square feet. It is found that, on an average, one square foot of thorn surface will evaporate 3·7 cubic feet of brine a day.

There is a good deal of loss, chiefly arising from the dripping brine being blown off the works by high winds. This loss is calculated at 12 per cent. There is always, however, a certain amount of loss of salt, even in tranquil weather, from atmospheric action.

There is also some loss from a double decomposition taking place between sodium chloride and magnesium sulphate, with the production of sodium sulphate, in frosty weather. On this account, the works are stopped in very cold weather.

It is said that alkaline carbonates, dissolved in the brine as bicarbonates, are deposited as insoluble carbonates, owing

to loss of free carbonic acid and of half the carbonic acid in combination, during graduation.

Thorn-stone.—Gypsum gradually accumulates on the twigs, and forms what is called thorn-stone. The composition of thorn-stone is as follows:—

Calcium sulphate	76·725
Sodium chloride	0·831
Potassium	0·429
Magnesium	0·102
Calcium carbonate	0·536
Potassium sulphate	0·239
Silica	0·152
Ferric oxide	0·074
Organic matter and water	20·912
	100·000

The twigs require to be removed every five or six years. They are called petrified sticks, and are used for ornamenting gardens.

In the cisterns, also, a quantity of matter forms, having a somewhat similar composition, and the consistency of mud. On the surface of this mud, a thick grey scum is thrown up, which is full of living infusoria, and gives off quantities of bubbles of gas, much of which is pure oxygen.

The work progresses precisely as at the Moutier thorn-houses. As the brine gets strong, loss from wind tells upon the produce, so that when the percentage of salt in the brine reaches 23, graduation ceases. At Nauhaim, graduation stops when the salt reaches 16 per cent.

The brine condensed by graduation is taken to boiling-houses and boiled during the winter months, as in Cheshire. Free ventilation is maintained at the surface of the liquor to carry off aqueous vapour. This vapour is found to con-

tain one per cent. of common salt, it is accordingly condensed and preserved.

During the boiling process, or *Schlotage,* a dirty brown scum of decomposed cremic and apocremic acids, and bituminous matter, appears on the surface of the brine. This scum has been analysed at Stassfurth, and Dunenberg, and has been found to have the following composition:—

	Stassfurth.	Dunenberg.
Calcium sulphate	54·908	62·436
Sodium chloride	26·090	14·909
Potassium sulphate	1·694	1·687
Magnesium ,,	0·762	1·440
Sodium ,,	2·964	6·856
Calcium carbonate	4·387	1·542
Magnesium ,,	0·971	0·211
,, chloride	0·221	......
Ferric oxide	1·158	0·285
Alumina	0·362	0·123
Silica	0·431	0·149
Organic matter	0·796	0·148
Water	5·256	10·214
	100·000	100·000

It will be seen that it is much more complex and injurious than the Cheshire scum. It is frequently raked from the surface and removed; but some of it falls to the bottom, where it augments the formation of pan-scale. After twelve or fifteen boilings, the pan-scale attains the thickness of an inch, and retards the boiling so much that it has to be removed. It is composed mainly of an insoluble double sulphate of gypsum and soda, enclosing sodium chloride, and is so hard, that it has to be cut out with chisels.

The following are the analyses of pan-scales, formed at the boiling houses of Schönebeck and Halle.

	Schönebeck.	Halle.
Calcium sulphate	27·381	62·981
Sodium chloride	44·284	29·028
" sulphate	20·667	......
Potassium "	2·125	......
Magnesium "	1·638	......
" chloride	......	0·243
Calcium "	......	2·431
Potassium "	......	1·310
Magnesium carbonate	0·408	1·905
Calcium "	......	1·265
Silica	0·023	0·533
Iron and alumina	0·030	0·304
Water	3·444	......
	100·000	100·000

It will be noticed that both the scum and the scale carry off a considerable percentage of sodium chloride, and that they are, therefore, a source of direct loss, as well as of injury to the boilers; the scum by interfering with evaporation and ebullition, the scale by absorbing heat.

Of the salts composing the scum and scale, calcium sulphate and magnesium chloride, are of no value, and are a hindrance to the extraction of potassium and sodium sulphate, which are valuable. The question is how to solve this difficulty? It can be done by the addition of sodium carbonate, which also augments the sodium sulphate, and produces an additional crop of common salt. The use of sodium carbonate, moreover, as before stated, prevents the formation of pan-scale. Having calculated the amount of lime and magnesium salts to be neutralized, a little less sodium carbonate than is required for the purpose is added, so as not to make the brine alkaline. The carbonate of soda determines a double decomposition, by the formation of calcium and magnesium carbonates, which fall, and sodium sulphate and

common salt, which remain. The reaction is as follows. $Ca\,SO_4 + MgCl_2 + 2\,Na_2CO_3 = CaCO_3 + MgCO_3 + Na_2SO_4 + 2\,NaCl$. The carbonates of lime and magnesia fall at first as a fine white mud, which afterwards crystallizes into a powder.

To accomplish this change, thoroughly, it is necessary to heat the brine up to 176° or 212° F. The common salt may then be separated by evaporation; but as it contains a little sulphate, it should be washed with weak brine. The remaining sulphates are easily separated from common salt, as they behave exactly alike, and differ from salt, in solutions; that is they both crystallize out at low temperatures.

Lastly, the potash and soda salts may be separated, as they also have different degrees of solubility.

This soda method of procedure, invented by M. Patera, economises fuel, as no scale interferes with the boiling. It also economises labour in the removal of scale. In the same way it economises time. The process of manufacture is developed to its utmost limits. More salt is obtained; and much more potassium and sodium sulphates. The salts extracted vary in value and so does sodium carbonate. The practicability of the process depends in a great measure upon their relative values.

It is found that when magnesium chloride is present in excess in the brine, or when sodium sulphate is deficient, a pellicle of salt forms upon the surface, resembling the wafer salt of out-door salt gardens. It, in like manner, retards evaporation. In the boiling-houses, the formation of this "scum salt," as it is called, is prevented, or arrested, by the addition of weak brine to the charge; or if that does not suffice, sodium sulphate is added, which enters into a double decomposition with the magnesium chloride, resulting in the breaking up of these too salts and the formation of common

and Epsom salts. We have frequently met with this reaction before. It results in stopping the formation of scum salt.

As soon as the salt crop begins to form in quantities, it is scraped out continuously and placed in wicker baskets, or heaped on slanting boards, beside the boiler. In either case the Mother-liquor is allowed to drain back into the boiler. The harvesting is stopped before all the salt is gathered, as after a time, magnesium sulphate and chloride begin to crystallize out, and appear as impurities with the salt. From the baskets, the salt is spread out to dry in a drying chamber; and as soon as it ceases to lose moisture, it is packed for

The Mother-liquor, or *bitterns*, as it is called in Germany, is subsequently used-up in the manufacture of Epsom salts and magnesium carbonate, in much the same way, as regards the changes which are induced in its chemical composition, as has been already described, p. 315 *et seq*.

The following are the results of the analyses of bitterns, at some of the more important boiling-houses:—

	Schönebeck.	Stassfurth.	Halle.	Moutiers.
Sodium chloride.........	15·057	13·623	6·494	20·80
Magnesium „	7·200	9·784	12·695	4·85
Potassium „	......	......	4·914	......
Calcium „	......	......	5·350	......
Potassium sulphate ...	5·358	5·177	......	......
Magnesium „ ...	3·522	1·526	......	9·50
Calcium „ ...	......	......	0·096	......
Silica	......	0·005	0·008	......
Alumina	......	......	0·042	......
Water	61·363	69·885	70·401	70·30
	100·000	100·000	100·000	105·45

At Kreuznach, and Salzhausen, appreciable quantities of

the Iodides and Bromides are found in the bitterns, which are consequently recommended for the use of patients suffering from scrofulous complaints.

The following table gives the analyses of common salt manufactured at some of the principal brine springs, that have not been specially noticed.

Analyses of Salts from Saline and Brine Springs.

Locality.	Schönebeck.	Artern.	Kissingen.	Cheltenham.	Caledonia, Canada.	Tarentum, U. States.
Per cent. of salt in water.	11·10	26·50	1·04	1·06	7·64	4·09
Sodium chloride............	93·72	95·35	75·30	80·90	84·31	78·24
Potassium ,, ...	......	0·45	0·62	......	0·39	......
Calcium ,, ...	......	......	......	......	......	13·66
Magnesium ,, ...	0·67	1·59	6·85	......	......	7·17
Barium ,, ...	......	......	......	......	......	0·93
Potassium bromide	......	......	......	......	0·22	trace.
Magnesium ,, ...	......	......	0·63	0·41	......	......
Sodium iodide	......	......	......	......	0·02	......
Magnesium ,, ...	......	......	......	0·06	......	......
Potassium sulphate	1·34	1·10	......	......	0·06	......
Sodium ,, ...	......	......	......	11·19	......	......
Calcium ,, ...	2·55	1·51	3·13	......	......	......
Magnesium ,, ...	1·18	......	1·60	1·37	......	......
Sodium carbonate	......	......	......	......	2·31	......
Calcium ,, ...	0·44	......	9·37	2·30	1·54	......
Magnesium ,, ...	0·05	......	1·88	0·92	6·77	......
Iron ,, ...	0·03	......	0·62	......	......	......
Silica ,, ...	0·021	......	......	0·37	0·56	......
Crenic acid	......	......	......	2·48	......	......
Carbonic acid	......	......	......	......	3·82	......
	100·00	100·00	100·00	100·00	100·00	100·00

Further information on the subject of aids to evaporation of weak brine by ropes, and thorn-houses, may be obtained from Bakewell's "Travels in the Tarentaise" and Knapp's

"Chem. Technology"; but these artificial aids to evaporation are rapidly going out of use, as it is found, on the whole, more economic to evaporate even weak brine, at once, by artificial heat. The spread of railways, cheapening fuel, have probably led to this result in Germany; but the facts noted will still be valuable to those, outside the pale of like civilization, who have weak brine springs to deal with.

CHAPTER XIV.

SALT LAKES.

It is remarkable that salt lakes are much more numerous in the northern regions of the globe than in temperate or tropical regions.

In this, and in other respects, they follow the lines of distribution of rock-salt deposits, more or less, closely. In Central Asia, from the Western shore of the Caspian Sea, to the Kinshan Mountains of Mongolia, with rare exceptions, nearly every lake is salt, in an area, at least, 3,500 miles in length.

The Elton Lake, in the lowest part of the great Aralo Caspian plain, is quoted as an example of the formation of rock-salt by deposition, as this lake is gradually evaporating and filling up with salt. Lake Kosiak, situated on the right bank of the Irtysh, in Asiatic Russia, is also annually depositing a considerable stratum of salt. So saline is this lake, that the crystals floating on its surface, when blown to the leeward shore, form ridges of salt, from which the people remove several million pounds of salt yearly. Messrs. Humbolt, Ehrenberg and Rose, who visited the Ural in 1842, give a remarkable account of Lake Inder. It lies in a basin above the level of the Ural river, surrounded by low sandstone hills. The bottom of the lake is an immense solid mass of salt, covered with a shallow sheet of brine. In the salt stratum are the orifices of several springs, down

one of which, a plumb line passed to a depth of 180 feet, without touching bottom. At the end of summer, the lake entirely dries up and is one solid block of salt. It would appear from this description that the salt in Lake Inder was formed by the evaporation of natural salt springs, leading from rock-salt previously deposited at the bottom of the lake. In the steppes of Asiatic Russia, salt lakes are very numerous. Besides those already mentioned, there are Lakes: Karashack, Kalkaman, Djemantons, on the right bank of the river Irtysh, and ten others, between the Irtysh and the Redoubt of Siberia. The great mart of Tobolsk is supplied with salt entirely from Lake Inder. There is salt enough in this region to supply the whole of Russia, but owing to the difficulties in the way of carriage, it is found more convenient to obtain salt from Lake Elton in the Kirghis. Lake Kupelnoye in Orenberg contains 16 per cent. of salt.

Lake Oroomiah, in Persia, situated 4,000 feet above the level of the Black Sea, drains a considerable tract of country abounding in rock-salt. It is 82 miles long by 24 broad.

There are numerous salt lakes in the interior of Thibet, some of them at a great elevation—14,000 to 15,000 feet above the sea-level. There is a group of a dozen or more salt lakes, at the northern end of the Black Sea, and at the entrance of the sea of Azof. These are centres of salt manufacture. The Crimean lakes are gradually salting. There are other salt lakes on the banks of the Volga. The Dead Sea in Palestine is a remarkable example of a salt lake below the sea level. There are salt lakes in Northern India. Not far from Lanarca, the Capital of Cyprus, there are extensive salt lakes. There are one or two in Germany. Captain Burton found salt lakes in the land of Midian.

There are numerous salt lakes in Africa. Near the Kaffir

country, to the East of the Cape of Good Hope, in South Africa, is one of those salt lakes which the Danish Colonists call *Zoutpans*. A traveller, named Barrow, quoted by Tomlinson, in his Natural History of Common Salt, remarks of it, "It is situated on a plain of considerable elevation above the level of the sea. The greatest part of the bottom of the lake was covered with one continued body of salt, like a sheet of ice, the crystals of which were so united that it formed a solid mass as hard as rock. The salt that is taken out for use is generally broken up with pickaxes, where it is four or five inches thick, which is at no great distance from the margin of the lake. The thickness in the middle is not known, a quantity of water generally remaining in that part."

Dr. Holub, ('Seven years in South Africa,') mentions his having visited three great salt lakes in South Africa. They are all very shallow. The longest and deepest lies near lake Ngami, and is only 4 feet deep. Dr. Shaw's "Travels"; p. 229, says that the salt pits of Arzew, in Algeria, the lakes between Carthage and Guletta, as those of the Shott and other places, bordering on the Sahara, in North Africa, dry up in summer and leave a thick bed of salt which is quarried for use. The lakes of Barbary are all saline.

In America there are several salt lakes. The great salt lake, at Utah, is a celebrated example. It has no outlet, and is gradually shrinking by evaporation, as is shown by the terraces around its margin, marking the old water levels. It is now nearly saturated, according to Professor Ramsay, who gives the following analysis of its brine. Sodium chloride, 20·196; sodium sulphate, 1·834; magnesium chloride, 0·252; and calcium chloride a trace, in 100 parts. (*Nature*, vol. 7, p. 313.) Salt lakes are found in Nevada in connection with rock-salt. There are many salt lakes in the Pampas of La

Plata, celebrated for the health of its cattle. Professor Agassiz noticed salt lakes in Peru at a high elevation—7000 feet—and found a salt water amphipod crustacean in Lake Titicaca, at an elevation of 13,000 feet. There are salt lakes in the South of Western Australia, the chief of which, Lake Austen, is 1,400 feet above the sea-level. Salt is manufactured from Lakes Poolenup and Muir.

It will be seen from the foregoing, that salt lakes are common throughout the world, and that they are found, like rock-salt, at various elevations above and below the sea-level. The question naturally arises how were they formed? As regards their origin, they may be broadly divided into two classes, those formed from the sea, by elevation; and those formed by the solution of rock-salt. The former are laying down new rock-salt deposits; the latter are dissolving old ones. It seems very probable that that portion of Central Asia, around the Caspian Sea, which now abounds with salt lakes, was formerly a great arm of the ocean. Herodotus (Chio. 203), Strabo (XI, 507), and Ptolemy, bear witness to the existence of a continuous ocean, spread over the centre of the great Asiatic plain, called the Hyrcanian Sea. M'Culloch (Geographical Dictionary) says, "On both sides of the hills of Mugodshak, and the countries lying south of it, between 45° and 64° East longitude, occurs the most remarkable depression on the surface of the earth. A tract of country extending over an area of more than 300,000 square miles, exclusive of the Caspian Sea, is, according to Humboldt, lower than the surface of the ocean. The lowest part of it is occupied by the Caspian Sea, which is 116 feet below the surface of the Black Sea, the lake of Aral being fourteen feet above the latter sea. The Caspian Sea, there can be little doubt, was formerly much more extensive on three sides, the north, north-west, and east." "On the east and

north-west, the land presents also incontestable proofs of having been formerly covered with sea water, the surface itself abounding in sea salt, sea-weed, marshes, salt pits and lakes, together with innumerable shells exactly resembling those of the Caspian Sea. Towards the east, the whole country has the same appearance of a deserted sea bed; and the conclusion, therefore, appears inevitable, that at comparatively no distant period, the sea of Aral, the Caspian, and the Black Sea, formed one body of water, uniting the present anomalous salt lakes of Asia with the ocean. This conclusion is further strengthened by the presence of the same species of fishes, seals, &c., in these seas, a fact which it is impossible to account for on the supposition that they were always separated. It may be mentioned that M. M. Lenormont and Chevallier hold the same views. (*Ancient History of the East*, vol. 1, p. 26.)"

We have already accounted for the formation of rock-salt deposits by the elevation of sea beds. In many salt lakes we have the process going on at present. In the Asiatic plains we have chains of salt lakes, which will ultimately form linked deposits in a horizontal plain; and the Great Salt Lake, Utah, will, in time, furnish an example of the less common form of isolated rock-salt deposit. According to Hayden, the loftiest peaks of the north-west mountains of the United States were beneath the ocean at a recent period. But there are other salt lakes, of which the Dead Sea is the most remarkable, which are formed by the solution of previously existing rock-salt. Some portions of the Cheshire salt valley are beginning to illustrate this process. In these cases the strata overlying large rock-salt deposits are undermined in time, as the salt beneath them is gradually dissolved and carried away by subterranean denudation. As they gradually sink below the surface, hollows are formed,

which in time extend to the dimensions of lakes, and are filled with salt brine from the springs below. Other salt lakes are formed by rain water, and streams, dissolving effloresced salt and surface outcrops of rock-salt in neighbouring regions, and carrying the brine into natural basins which, having no outlet, concentrate by evaporation. Such is the origin of Lake Oroomiah in N. W. Persia.

The Bitter Lake, in the Suez Canal, furnishes a curious example of a salt lake formed partly by the sea, and partly by solution of rock-salt. Rock-salt was found in a considerable depression in the Suez Canal, into which the sea was admitted, when the canal was flooded. The comparatively weak sea brine, dissolving rock-salt, formed the Bitter Lake.

The Dead Sea is worthy of special notice. It occupies the valley of Siddim, in Palestine, in which stood formerly the cities of Sodom and Gomorrah. It is called in Scripture the Salt Sea; by Josephus and other Greek and Latin authors, *Lacus Asphaltitis*, from the presence of bitumen on its shores; and by the Arabs, 'Stinking Sea.' It contains 103·6 per mille of sodium chloride, and 102·4 per mille of magnesium chloride; this, with 3·92 per mille magnesium sulphate, are its dissolved solids. It is, therefore, a tolerably strong brine of sodium and magnesium chlorides. At the south-west corner of the lake, still called *Usdum*, where formerly stood the city of Sodom, a large mountain, or range of mountains, composed in great measure of rock-salt, overlook its shore. The salts of the lake are, doubtless, derived from these mountains, by denudation. Lieut. Lynch, who examined and reported upon the Dead Sea, for the United States Government, remarked, that when disturbed by storms, its waters, owing to their density, subsided again with remarkable rapidity. "Within 20 minutes from the time we bore away from a sea which threatened to engulf us, we were

pulling away at a rapid rate over a placid sheet of water, that scarcely rippled beneath us." The lake is about 50 miles long, by ten broad. It is shallow for about fifteen miles at its southern extremity. Over the site of the submerged cities, its depth varies from one to two fathoms. The rest of the lake is deep enough; and near the northern end, it varies from 150 to 218 fathoms. The bottom consists for the most part of blue mud, sand, and salt crystals. Some crystals, fished up by Lieut. Lynch from a depth of 1,020 feet, were "perfect cubes." Salt is not manufactured here as it is found rather commonly in the neighbourhood, and the quantity of magnesium chloride present is excessive.

As a general rule the manufacture of salt from salt lakes is left entirely to nature, and the salt is quarried from the dry bed of the lake. But at the Sambhur Lake, in the Rajpoot District of Hindustan, art assists in accelerating the process, which will be described. Bay salt has been manufactured for centuries at the Pulicat and Chilka Lakes, on the Coromandel Coast; but these are really estuaries, supplied with brine from the sea, and the method of salt culture pursued in them is the same as that described in the Chapter on the 'Working of Salterns.'

The Sambhur Lake is situated in Jodhpoor, and was taken over by the British Inland Customs, in February 1870. It is rather irregular in outline. Its greatest length is 20 miles, its average breadth 4 miles, and its average depth 2 feet.

About August, after the monsoon rains, or those which accompany the South-west trade winds, the lake contains brine of the density of sea water. At this time it marks 3° Beaumé, and there is no difference in point of density between the surface brine and that at the bottom of the lake.

The surrounding country is said to be composed of rocks abounding in limestone and salt, and belonging to the *Per-*

mian system, and it is supposed that the salt of the lake is derived from the washings of this system.

The bottom of the lake consists of tenaceous black mud, resting on loose sand. Beneath this comes a black micaceous sand, getting hard at a depth of 10 feet. No rocks are found until a depth of 20 feet is reached. The basin of the lake shelves very gradually down for 3 miles from the shore.

Wells sunk in the sand, surrounding the lake, yield brine, strong or weak, according as they are near or far from the lake, but in no case is the well brine as strong as that in the lake.

After the rains, the lake begins to evaporate. It evaporates almost uninterruptedly from October to June. It is said that the rate of brine evaporation during the hot weather reaches half an inch a day.

The rain-fall is almost confined to the months of August and September. It averages 18 inches annually.

About April the lake dries up and exposes a wide bed of salt, having a rosy pink tinge. The colouring matter has been analysed and found to be organic. It is attributed to the presence of microscopic algæ. The greater part of the salt obtained from this lake is really spontaneous; there is a certain amount of method followed, however, in its collection.

As evaporation proceeds in the lake, its waters contract and gather towards its centre and deeper parts, leaving a space of about 2 miles, round the margin, dry. Now, as the buildings for storing salt, etc., are all some way from the extreme margin, it would add very much to the expense of salt storage to collect it from the centre of the lake. But it happens, also, that the exposed belt of silt, left dry by the retreating waters, is dry only in appearance, and that it is

impossible to walk upon it without sinking knee deep in mud. It follows, that some means must be taken to keep the brine from retreating from the shore. It is just a provision of this kind which constitutes the active interference in the natural work of salt formation at the lake. Mud walls are thrown up, enclosing a long shallow section of the lake, and its waters are thus retained in one place until they evaporate and yield up their store of salt. The actual salt field in 1870, was 411 acres.

The mud walls are from $1\frac{1}{2}$ to 3 feet high, according to the depth of brine, and are made in the following way. Suitable stakes are driven into the mud, in two rows, 18 inches apart. The rows are then lined inside with long grass, and the frame work thus formed is filled up to the top with the stiffest mud procurable. It is found, that owing to the antiseptic action of the salt, with which these walls are in time impregnated, the woodwork lasts for a long time. In some cases, with occasional repairs, for twenty or more years. As these walls are the back bone of this method of obtaining lake salt, and no timber grows naturally in the neighbourhood, the officers employed at the lake endeavour to rear up plantations of suitable wood. They have lately met with a fair measure of success in planting.

As soon as the salt is formed, native labourers, men and women, wade out to it with baskets. To reach the thick crust of salt, they have to wade some 300 or 400 yards, ankle deep, through soft, fœtid mud, loaded with sharp-edged salt crystals, which often cut their feet and cause the formation of ugly sores. It is said that this mud stinks a good deal. These salt gatherers insert their outspread hands under the salt crust, and lift it off, in good sized cakes, which are placed in baskets, and brought to shore. Men bring to shore, in this way, about half a ton of salt a day. Women,

less, in proportion. The largest salt crop was obtained from the lake in 1839, before it passed into the hands of the English Government; it amounted to 73,330 tons.

The salt cakes soon fall to pieces and furnish a quantity of bluish grey, opaque crystals, having the appearance of truncated pyramids. The pyramids, or hoppers, are half an inch long from base to apex. They resemble 'bay salt' crystals in appearance, but are harder and firmer. One square foot of salt cake is said to weigh 4 lbs.

The salt is heaped in conical or oblong pyramids, sloped to an angle of 36 degrees, and containing from 500 to 1,000 tons each. They are beaten and smoothed, as a protection from rain, but not covered. The wastage amounts to about three inches of surface salt per annum. When weighing salt for sale, only 10 per cent. of each transaction is weighed.

Besides the large salt field, there are a few salt pans of an artificial type, here and there, where the lake is too deep to evaporate to dryness naturally. These pans are surrounded by staked walls, larger than the field walls, but made in the same way. They are also clayed artificially, and their floors are beaten hard.

The Journal of the Asiatic Society for 1836, gives the following as the analysis of the clay floor of a pan, sometime in use:—

Silica	33·4
Sodium chloride	12·4
,, sulphate	6·7
Calcium carbonate	7·7
Alumina, iron oxides	3·6
Water	35·6
	99·4

Brine from the lake is bailed into these pans to a depth

of three or six inches, according to the weather. It is not saturated, but ordinary lake brine. It evaporates in about a month, according to the weather, and the salt is scraped up with rakes, and removed to the stacks, where it drains in the open. There is nothing in particular worth noticing about these proceedings. It has been already noticed that, in the cold weather, sodium sulphate is formed in the lake at night, and re-dissolved in the day, and that large prismatic perimorphs of sodium chloride are formed on the Glauber's salt crystals. In the artificial pans, twigs are sometimes placed, and the salt is allowed to crystallize upon them; the salt crystals are then shaken off the twigs, back into the pan, and this causes each crystal to grow to a fine size. This, however, is more of an experiment, than a serious effort to manufacture large and regular crystals. In time, the bottom of the artificial pans gets covered with a hard scale, having the following composition :—

PAN SCALE.

	A pan.	B pan.
Sodium sulphate	57·0	57·5
„ chloride	24·5	18·1
Calcium carbonate	11·0	10·6
Insoluble residue	1·8	2·0
Organic matter and loss	3·3	1·8
Water	2·4	10·
	100·0	100·0

Analyst—Dr. Warth.

It is to be observed that this pan-scale differs from that hitherto noticed, in the presence of calcium carbonate, and absence of calcium sulphate.

The following is an analysis of the Mother-liquor from the artificial pans :—

Sodium chloride............	19·1
„ sulphate	7·1
„ carbonate.........	4·4
Dry residue (?)	0·6
Water	68·8
	100·0

Analyst—Dr. Warth.

The above analysis is taken from the Bengal Inland Customs Report of 1871-72.

The following table of analyses represents the composition of the brine in some of the principal salt lakes :—

	Lake near Ararat.	Lake Elton.	Bitter Salt Lake.	Putrid Lake.	Sambhur Lake.	Laacher Sea.	Lonar Lake.
Sodium chloride......	213·6	13·124	10·54	14·20	19·9	0·1791	6·0
„ sulphate ...	55·7	......	......	......	1·6	0·0959	trace.
„ carbonate ...	37·0	......	......	......	0·4	1·1259	70·0
Magnesium chloride.	......	10·542	9·91	1·93	......	......	...
„ sulphate.	......	1·665	8·22	1·21	......	......	...
Calcium carbonate ..	......	......	......	......	......	0·5898	...
Magnesium „ ...	......	......	......	......	......	0·2112	...
Potassium chloride..	......	0·222	......	......	......	......	...
Calcium sulphate ...	......	......	......	0·04	......	......	...
Magnesium bromide.	......	0·007	......	......	......	......	...
Organic matter......	......	trace.	......	......	......	0·0295	...
Insoluble residue ...	......	......	......	......	21·9	......	0·5
Water	......	74·440	71·33	83·62	78·0	......	20·6
	306·3 in 10·000 parts.	100·000	100·00	100·00	99·9	2·1814 in 10·000 parts.	100·0

Analysts—Abich. Gobel. Gobel. Gobel. Bischof Karsetn.

The Caspian Sea and the Sea of Azof may be looked upon as large salt lakes, much diluted with fresh water. The former contains, according to Rose—sodium chloride,

0·0754; magnesium bicarbonate, 0·0440; calcium sulphate, 0·0406; sodium sulphate, 0·0036 in 100 parts. And the Sea of Azof, sodium chloride, 0·9658; magnesium chloride, 0·0887; magnesium sulphate 0·0764, calcium sulphate, 0·0288; magnesium bicarbonate, 0·0129 and potassium chloride, 0·0138, in 100 parts.

CHAPTER XV.

SPONTANEOUS SALT.

The term spontaneous salt is placed above to represent everykind of naturally formed surface salt, including effloresced salt. Strictly speaking, swamp salt and effloresced salt are the only purely natural products of this series, and, therefore, the only ones entitled to the name of spontaneous salt; but as the manufacturing element is not very largely concerned in the production of the other salts to be mentioned, as ice salt, all are classed together, here, for convenience.

In many tropical and sub-tropical regions, as on the East Coast of Hindustan, the sea breaks in upon the land at various low lying situations, near the mouths of rivers, whose deltas, formed during periodic floods, lie bare in the dry season. Caught in the shallow basins of the undulating soil, the sea is here retained and evaporated long enough to permit of its depositing the greater part of its sodium chloride, before the brine leaks away. Swamp salt forms in extensive cakes, about an inch thick, upon the surface of these litoral wastes; and it is remarkable for the weight, solidity, and purity of its crystals. These deposits may, in time, reach a thickness of two or three feet, as in Scinde, where Lieut. Burke rode over a salt crust, for miles, without making any impression on it with his horse's feet. (Burke J. H., "India salt.")

The following table exhibits the results of analyses of

specimens of Madras, and Bombay swamp salt, and of Calimere spontaneous salt.

The analyses are given in the dry state, and free from mechanical impurities, with the object of comparing swamp salt, with rock-salt.

	Calimere spontaneous salt.	Scinde swamp salt.	Madras swamp salt.
Sodium chloride.............	98·95	97·69	97·46
Magnesium ,, ...	trace	0·20	0·21
Calcium ,, ...	0·01	trace	trace
Magnesium sulphate	......	......	0·13
Calcium ,, ...	0·11	1·73	0·02
Loss	0·93	0·38	2·18
Total...	100·00	100·00	100·00

It will be seen that the above analyses correspond very closely with those of rock-salt, given at page 116. The nascent and the developed stages of rock-salt are alike in composition; differing from each other only in form; a difference which has been already accounted for.

The remarkable absence of magnesium salts from swamp salt is attributable to the fact that the swamps are porous; the bitterns being heavy, and difficult to evaporate, are carried off by leakage. At point Calimere, on the Coromandel Coast, the formation of swamp salt is assisted by artificial embankments, and the product is called *spontaneous salt.* Two long lines of mud walls, about six feet high, are run out parallel to each other into the swamp, in the direction of the tide, and are connected with each other, at intervals of one hundred yards, by similar embankments, placed transversely, so as to form a series of reservoirs, in line, resting on the level swamp. They are of large size, and open into each other from end to end, by means of a row of wooden, sluice gates, in masonry frames. The rear wall of

the first, or mainland reservoir, communicates with a canal, cut in the swamp; the gate of the last reservoir opens far out, in the direction of the sea. When the annual *monsoon* wave rolls across the swamp, in June, the sluices are left open, that the sea may enter and fill the reservoirs; and when it has attained its highest level, the sluice of the last, or outermost reservoir, is closed, whereby water is retained in all. The other sluices are closed afterwards, to counteract wave motion and wind drifting. Having closed the sluices, all the preparations are complete. The water is allowed to evaporate without further interference until salt forms; and if the season is a fortunate one as regards weather, a large quantity of excellent salt is obtained. In the ten years ending 1874-75, about 29,000 tons of salt was obtained at Calimere in this way.

On the Canning, in Western Australia, a good deal of this kind of salt is also formed. Also in the salt marshes of the coast of Florida, and on the creeks of the Gambia.

In the Joazeiro district of Brazil, along the banks of the Rio de Salitre river, an artificial hollow extends for the space of 60,000 square feet. Soft yellow loam forms the lining of this hollow. The annual floods dissolve the salt in it, and when the river falls, a salt pool is left. The heat of the sun then evaporates the water, and the surface is left covered with spontaneous salt, which is gathered for use.

At Huacho, in Peru, some very remarkable spontaneous salt is formed in what is described as a natural ocean saline. Sea water percolates through a flat, stony shore, and oozing to the surface, evaporates, leaving the stone covered with an extensive slab of very pure salt. Tschudi compares it to a glacier in appearance. Chili and Peru are supplied with excellent salt from this source. (Tschudi, Peru, Bk. I, p. 308.)

Superficial deposits of spontaneous salt are occasionally

formed at a considerable distance from the sea, owing to the action of earthquakes in raising great sea waves. The country around Masulipatam, on the east coast of India, was flooded, some years ago, by a sea wave of the kind, which did great damage to life and property. During the famous earthquake of Lisbon, the sea rose to a height of 60 feet at Cadiz. In volcanic neighbourhoods such waves are not uncommon.

Another natural phenomenon may be mentioned, which sometimes occasions the formation of spontaneous salt at a distance from the sea, viz., the carriage of salt water inland by water spouts. On the night of October 14, 1879, an immense water spout, which had been formed in the sea, at a distance from the coast, passed over and inundated the city of Mercia in Spain. On this occasion, salt water was discovered at a distance of 45 kilometres from the sea.

It is difficult to form even an approximate estimate of the quantity of spontaneous salt scattered over the globe; but it must be very large. Lieut. Burke estimates that the salt in a swamp near Kotree, in Scinde, amounts to 929,280,000 cubic yards, or 1,484,151,430 tons; and that at 20 lbs. per head per annum, it would supply a population of 100,000,000 for 1662 years. He also states that this is only one, and not the largest, of several similar beds existing in the Run of Kutch. Along the Coromandel Coast there are several large swamps, in which thousands of tons of salt form annually.

Singularly enough, from a revenue point of view, these rich deposits of pure spontaneous salt are not always looked upon as an unmixed blessing. In some countries, in which the manufacture and sale of salt is a Government monopoly, these deposits constitute a difficulty for the Revenue Department. They offer a very tempting inducement to the poor to gather this essential necessary free of duty. Spon-

taneous salt is, therefore, watched and very zealously gathered and guarded, *or even destroyed,* as soon as it forms; and heavy penalties are imposed upon those who are found appropriating it to use. In the Madras Presidency hundreds of natives are yearly convicted of stealing it. The question of its disposal is an important matter. One would imagine, considering the general excellence of swamp salt, that the best thing to do with it would be to gather it and sell it with the ordinary manufactured salt of the country. But it is sometimes almost impossible to do this, from the inaccessibility of the locality in which it forms; the absence of fresh water, and the necessaries of life; difficulties of transport; scarcity of labour; and country prejudices. Moreover, owing to the above causes, such salt brought into store, is generally much more expensive, and therefore less profitable, than manufactured salt. To guard the salt as it lies exposed in the swamp, would be an expensive way of perpetuating a standing menace to the revenue. It is, therefore, generally destroyed. In former days, Indian swamp salt was always destroyed by being trampled under foot by herds of cattle, brought from a distance, and turned into the swamp for that purpose. Now, other and more effectual means are at times employed. The cattle, after all, put the salt out of sight and soil it, rather than destroy it. It sinks into the mud, and remains there, and may be easily extracted and washed for use. The following are some of the means suggested for the prevention or removal of such formations: Draining the swamp. Sinking wells at its lowest level, into which the brine, contracting with increase of density, may subside and deposits salt out of harm's way. Flooding the swamp from a fresh water irrigating channel. Embanking it from the sea. In considering the cost of such works, the loss of revenue from

thefts, imprisoning, and guarding, have to be taken into account. It is advisable, when possible, to establish salt works where large collections of spontaneous salt are found. Places which nature has selected, as it were, for spontaneous salt deposits, are usually such as present first rate natural facilities of soil, brine, level, and climate, for the cheap and extensive production of bay salt. But, unfortunately spontaneous salt, more than any other kind of salt, excites the prejudice of the ignorant.

In some places, on the Madras Coast, spontaneous salt has acquired such an evil reputation, as producing diarrhæa and skin diseases, that people will not use it. It will be seen from the description of the theory of the separation of salts from sea water, already furnished, that when the process is continued to dryness, in an impermeable bed, the salts deposited will form layers, corresponding to their degrees of solubility; the less underneath, the more soluble at the surface, because they are deposited last, so that sometimes there may be on the top of the common salt, an appreciable quantity of magnesium sulphate; and in countries visited by cold winters, sodium sulphate, and the double sulphates, and chlorides, before mentioned, on the top of all. These salts, *might*, according to the analyses given, form one-fifth of the whole deposit. Lieut. Burke, who first brought the spontaneous salt beds of Scinde to public notice, remarked upon the repugnance of the people to use the salt there. The same prejudice has been often noticed elsewhere. Strange as it may appear, read in the light of these facts, it is intelligible; for it is possible that the people may have helped themselves from surface salt, and so missed the sodium chloride altogether. Notwithstanding these theoretical considerations, however; and the prejudice which exists in certain localities, beyond denial; the great bulk of swamp

salt is pure, and even exceptionally pure. The soluble salts, when left on the surface are, almost always, completely washed away by rain, leaving nothing but common salt behind; and generally speaking, swampy soils are so porous, that the injurious salts leak away with the mother-liquor and are not deposited at all.

A curious variety of spontaneous salt forms in deep pits, in salt swamps, into which brine has contracted, or has been carried by floods. This salt, formed slowly, in a deep, tranquil, and not highly saturated fluid, with but a small evaporating surface, compared to its volume, is often very perfectly crystallized and very pure. It is obtained in the shell pits of the Pulicat Lake. At a place called Morekolam, in the Madura District of the Madras Presidency, there is an old sacred tank attached to a Hindoo Temple. This tank is 185 yards long by 120 broad. At one time, its waters were fresh, and it was used by the frequenters of the temple for the purpose of bathing, as is attested by tradition and by the ruined flights of steps, still visible, leading down to the water. It is said that about the beginning of the present century, an attempt was made to deepen the tank, which resulted in opening its floor into a loose subsoil stratum, containing strong brine, which rose at once in level, and half filled the tank. Upon this, the tank was abandoned, as its water remained permanently saline. Since then, it has from time to time, dried up, exposing a thick bed of beautiful salt crystals. When the author saw it, the tank was saline, but very far indeed from being saturated with salt. It marked 5° Beaumé at the surface, and 12° B. at the bottom, in contact with the salt, and its depth was about seven feet. The crystals taken from the bed of the tank, were pyramidal in shape, composed of steps, of small, scarcely visible cubes, perfectly crystalline in structure. Some of the pyramids were an inch and a half in height, from base to apex, and all were of a translucency bordering on transparency. Deeply formed salt always excels in point of crystallization, but this was a particularly rare and beautiful specimen. This salt is only found in small quantities, and is merely a curiosity.

Effloresced salt.—In dry hot regions, in which the soil is saline, surface moisture evaporating, leaves a deposit of salt in the form of a fine white powder upon the ground. This

is called *effloresced salt.* It is found in the rainless districts of the Cordillera, in South America, in the region of the great Salt Lake, Utah, in the Steppes of Russia, the Northern Provinces of India, on the borders of the Sahara and the Dead Sea, and in fact wherever salt lakes, brine springs, or rock-salt abound.

It is also found in the neighbourhood of the sea; and has for its source, recent or remote, either rock-salt or the sea itself.

Effloresced salt occasionally appears in the form of a brilliant crystalline powder, pure enough for immediate use. Such salt was seen by Captain Burnaby in the Turkish District of Anatolia, (Ride to Khiva.) But more often it gives the ground a greyish appearance, and the salt is mixed with earth in various proportions.

Not unusually common salt undergoes a partial decomposition in the soil, with the formation of sodium carbonate, as described at pp. 43, 193, and the efflorescence is consequently mixed in composition. This appears to be the origin of what is called *rheh* in Northern India. Sometimes, sodium sulphate is formed in excess, by the reaction of magnesium sulphate and common salt, under the influence of cold.

In many places effloresced salt is the only form of salt available for use. In India, it is called "earth salt," and it forms the bases of a separate kind of salt manufacture, as in the Ceded Districts of Madras.

On certain coast lands efflorescence of salt denotes a highly impregnated state of the earth, and this earth—called "salt earth"—is likewise often used as the basis of a peculiar kind of salt manufacture as on the Malabar Coast. Salt earth is generally found at the top of loose loamy soils, near the sea, which are either flooded by high tides, or permeated by subsoil brine. Salt efflorescence makes very

little alteration in the appearance of the surface soil. To unaccustomed eyes it would pass unnoticed. There is no whitening of the surface, at least none that would strike an ordinary observer. Yet maritime salt earth is peculiar, and very easily recognized by those who know it. The surface of the ground is covered with a soft pellicle, or mould, of the colour and thickness of dirty brown Chamois leather, in pieces about the size of the palm of the hand, or smaller, and curled up at the edges. Beneath this covering is a very distinct gray-coloured, powdery looking earth, which is composed of a mixture of sodium chloride and loam. This earth has furnished on analysis as much as 69 per cent. of sodium chloride; and the author believes that he has seen earth samples containing even a larger percentage of salt.

It is not to be wondered at, that with so strong a mixture of impure sodium chloride with earth, at hand, the natives of the Coast prefer it to sea water, for the manufacture of common salt. All it requires, to convert it into edible salt, is lixiviation and evaporation; and there is the salt water of the sea wherewith to dissolve it, and the strong sun for its re-evaporation, daily available. There can be no doubt that were the supply of salt earth abundant, and concentrated in one locality, it would be very much more profitable to manufacture salt from it on a large scale, than from sea water. A single lixiviation yields a nearly saturated brine; and a measure of salt earth yields from one-third to one-half its weight of salt. But the reverse is the case. Its formation is characterized by extent of surface-distribution, rather than by amount; and it is unsuited, therefore, for the purpose of wholesale manufacture. On the other hand, for the native, whose wants are small and who gives his own labour to the work, it is most suitable. To those who wish to escape the tax it affords a ready means of procuring salt duty free;

and next to swamp salt, it is on the Coromandel Coast, a fertile source of illicit transactions. A few quotations from the Report of the Madras Salt Commission, will illustrate this point. With reference to Ganjam, a maritime district in the North of the Madras Presidency, the Report says, "In the first three months of 1872, some 10,000 maunds (=367 tons) of earth salt were seized, and 2,000 persons punished. Seizures continued to be frequently made, and in August 1873, Government sanctioned the addition to the district Police force of a special body consisting of an Inspector and 25 Constables for the detection and prevention of offences against the salt laws. These men appear to be now employed in guarding the salt swamps abovementioned, a task for which they are quite insufficient; and, notwithstanding, all these measures, the use of illicit salt is far from being suppressed, no less than 9,549 maunds (348 tons) having been seized in 1875-6." The salt swamps referred to in this extract, are about 50 square miles in extent. Still, dealing with this subject, the Report goes on to say: "In South Arcot and Madura, the Collectors state that the manufacture is extensively prevalent. In 1871, the Inspector-General of Police reported that the manufacture was increasing in South Arcot, 42 cases having been reported in 1867; 45 in 1868; 48 in 1869; and 98 in 1870. Sixteen cases were reported in Madura in 1870." A falling off in the sale of monopoly salt owing to the consumption of earth salt having been brought to the notice of Government, the Report goes on to say: "In consequence of this information the Police set to work, and 101 cases of illicit manufacture were put before the different Magistrates. Convictions were obtained in 99 of these cases, and 359 persons were punished with fines, amounting to Rs. 1,023. Salt valued at Rs. 260 was seized. The authorities of the Rail-

way Company, had, at the same time, brought the decrease in their salt traffic consequent on the earth salt manufacture to notice, * * * * and again in 1875, they called attention to the matter." These extracts are sufficient to show that the facilities for making earth salt are so great, and so tempting, considering the salt monopoly, that the natives cannot resist the desire of making it, when the opportunity offers.

On the Coromandel Coast, earth salt manufacture is a very simple affair indeed. The salt earth is placed in an earthenware vessel, with a small hole in the bottom, plugged with straw or cotton wool, to keep the earth from falling through, and sea water is poured upon it in a gentle stream. As the sea water filters through the earth, it dissolves the greater part of the sodium chloride, and carries it away in solution; and as the brine falls through the plug, it is caught in a vessel underneath. The nearly saturated brine, obtained in this way, is then evaporated by solar heat, or by boiling, according to circumstances of weather and chances of detection.

A much more elaborate system of salt manufacture is practised on the Malabar Coast, on the borders of the Arabian Sea. On this Coast, for some reason or other connected with the ancient rights and privileges of the inhabitants, the manufacture of earth salt, notwithstanding its detriment to the revenue, is not prohibited; though the sale of earth salt is, and much pains are taken to suppress its illicit distribution. As the people are allowed to make it for their own use, they do so systematically. The locality selected is a dry, flat swamp, well supplied with salt earth, and situated close to the sea, or on the banks of an estuary furnishing salt brine. In the first place the labourer builds up a mound of earth, five or six feet high, and hollows it out within, to form a filter.

The inside wall, or lining of the filter, is plastered with clay, and at the bottom, a small opening, communicating with a brine channel, is also lined with the clay. The channel at the foot of the filter leads to a deep pit. This pit, which is intended to serve as a reservoir of strong brine, is also well plastered with clay within. The evaporating pans are constructed, at a distance of a few feet. These pans are often raised a few inches from the ground, on an earthen platform. They average about 342 square feet in area, and are divided, by small clay partitions, into a number of miniature crystallizing beds, about 18 inches square, well plastered with black clay. The extent of land taken up by each entire salt work is about one-fourth of an acre. These works are constructed in February; and manufacture begins about the beginning of March. First, twigs and straw are placed over the opening in the bottom of the filter, to prevent earth from falling through, and salt earth is collected from the surface of the ground about the pans, and the filter is filled with it. The filter, it should be noticed, is cylindrical, about two feet in diameter, and three feet deep; it holds, therefore, a little over nine cubic feet of earth. Next, salt water is poured upon the earth until the reservoir is full. Brine begins to trickle through into the channel below, and on into the reservoir, where in about three hours the whole of it is collected. The density of the brine obtained in this way varies a good deal according to the salinity of the earth used, but it averages about 19° Beaumé. Work begins early in the morning, so that by 9 A. M. sufficient brine for crystallization is collected in the reservoir. This brine is then carried in pots to the crystallizing beds, and is poured out in a thin sheet, half an inch in depth, and left to evaporate. By evening, the greater part of it has evaporated, and the salt crop is ready. The crop is scraped, with care, by

means of a thin bamboo lath. The crop ordinarily amounts to about 2·5 cubic feet, or to rather more than one-fourth of the bulk of salt earth used—that is, with good salt earth and favourable weather. The bitterns left in, after the manufacture, average about 30° Beaumé in density. They are removed as it is generally necessary to remake the pans with clay, each morning. The salt itself is cubic in shape, and rather large grained, considering the process; *i.e.*, each crystal may be one-eighth of an inch in diameter; but the crystals are very hollow, light, and friable, and they are coloured dark by mud stains. One small family, or part of a family, a man and his wife, with one or two children, conduct the business of salt manufacture; and very often the greater part of the work is done by women and children, whilst the husband fishes, hard by.

In Normandy, the salt sand recently uncovered by the receding tide, and dried by the sun, is gathered by means of a broad scoop, drawn by horses. The sand is then transferred to filters; the salt washed out; and the brine boiled down for salt, in leaden boilers.

On the South Coast of Java, and in some parts of Brazil, a somewhat similar method of salt manufacture is pursued; but the salt earth is first artificially strengthened. The natives scrape up the sand on the sea shore into long low ridges; they then fill watering cans from the sea, and run along the ridges, pouring salt water on them as they run. This is done during the heat of the day, and solar evaporation causes a certain amount of salt to effloresce at the surface. The surface sand is then gathered and crammed into a rude funnel, and the salt is extracted by lixiviation, with sea water. In this way, a strong brine is obtained, which is boiled down in pots, and the salt crystallized out.

Another method of obtaining salt, in use on the Channel

Coast, is described in Maigné's "Arts and Manufactures," Paris. A large quantity of sea sand is washed with sea water until a good brine is obtained, this is then evaporated to dryness, and the resulting impure salt is suspended in baskets over steam. The magnesium salts take up the watery vapour and deliquesce out, leaving a very pure salt in the basket. This is kept for some months, during which there is a further loss of from 28 to 30 per cent. of weight. The salt is then very pure, fine, and white; and is known by the name of *igniferous salt.*

There appears to be a waste of time, labour and fuel in these methods, as compared with the process of bay salt manufacture already described; but they are confined to places in which solar evaporation is not often feasible, and probably to localities in which clay, for salt pans, is not available.

In the interior of the Indian Continent, also, common salt is manufactured from salt earth. The richest salt earth is found in the lines of drainage, and lower levels, to which salt is carried in solution. In the districts of Bellary, Cuddapah and Kurnool, the manufacture of salt from saline earth is extensively followed, and by a distinct class of men, who possess a hereditary right to this occupation. From the report of Mr. Thornhill, C.S.I., Senior Member of the Madras Board of Revenue, who has specially written on this subject, it appears that the manufacturers are poor, and quite of the labouring class; when not making salt, they hire themselves out for other works, or hawk the salt about the country. Mr. Thornhill says, "They are as a body undeniably poor; so far as I could learn, there is not a rich man amongst them. It was acknowledged on all sides, that, beyond making a livelihood for about half the year, they had no tangible profit, * * *. A certain amount of property is

acknowledged to exist in the modas, (salt works), and occasional disputes arise; but they possess *no saleable value whatever*, and no one ever heard of a salt moda being attached for arrears of revenue, or in satisfaction of a decree of Court."

Their method of manufacture is very similar to that adopted on the West Coast, which has been already described. Their works of construction are however, more elaborate, inasmuch as they coat the inner surface of their reservoir with cement, use cemented brine channels, and their salt, or crystallizing beds, are also coated over with a plastering of lime cement, well smoothed. The salt works are tended by men and buffaloes, one or more, according to their size, but ordinarily, two men and one buffalo suffice. The salt earth is collected in the neighbourhood of the works. Mr. Thornhill states that, "Its presence is discovered by the powdery appearance of the soil * * *. It is by no means universally the case that the efflorescence of common salt whitens the ground. When the ground is whitened it is generally by the presence of soda, known to the people as washerman's earth * * *. The powdery surface only is scraped up, and it takes a considerable time to collect a buffalo load. Sometimes, men have to travel from one to two miles to procure a sufficiency of earth to fill the basin." In the evaporating process, also, more time is occasionally, or in some localities, allowed, for the formation of salt crystals; and the accretion system is practised on a small scale, for about eight days.

The salt resembles very closely that kind of sugar in which the crystalline particles are distinct, and about the size of snipe shot. It is, as a general rule, a much cleaner salt than that made on the Coast, and the samples, from clean cement beds, are as white as whity brown sugar. The

quantity of this salt, manufactured annually, is very small. It is estimated at 16,073 tons.

Nine specimens of earth salt, three from each district, were analysed for the Madras Salt Commission, by Dr. Hazlett, with the following average percentage-results :—

	Cuddapah.	Bellary.	Kurnool.
Sodium chloride.........	81·252	82·305	84·861
Magnesium "	2·628	1·683	2·538
Calcium "	......	0·463	0·144
Magnesium sulphate...	......	0·264	......
Calcium " ...	1·733	1·242	2·241
Sodium " ...	4·742	5·339	4·490
Inorganic residue	0·868	0·815	1·351
Organic matter	0·123	0·083	0·129
Moisture	6·563	8·250	3·876
	97·909	100·444	99·630

One of the specimens analysed, contained 16 per cent. of sodium sulphate. Nitrates were indicated in one specimen only. Inland earth salts do not run on all fours with Coast earth salts, as they are centuries older, and have undergone in many cases chemical alterations. The particular samples analysed, as shown above, appear to have been singularly free from sodium sulphate, which, as is well known, is largely found in the soil used in the manufacture. They contain calcium sulphate, as probably no opportunity is afforded for its deposition, before the brine is poured on the pans; and they are very free from insoluble residue, otherwise called dirt, owing, no doubt, to the use of artificial cement beds. Some fifteen other specimens of earth salt, from the same districts, were partially analysed for the Madras Salt Commission, and the Commission remark, "The Bazaar specimens were presumably intended for human consumption, and some of them show only 52, 69, and 71 per

cent. of chlorides. The worst sea salt gave 74·6 per cent. of chloride of sodium; and if the balance of the specimens of earth salt just adverted to consisted, as is probable, of sulphate of soda, the salt cannot be wholesome; sulphate of soda being a strong purgative." The cost of this salt is estimated to be from 3*s*. 6*d*. to 14 shillings a ton. It varies according to the supply of salt earth. The average profit to the owner seems to be about 9 shillings a ton.

This feeble and irregular manufacture of common salt, has been condemned, and there is every likelihood of its suppression, with adequate compensation to the owners of earth salt works, within the next few years.

In considering the source and origin of spontaneous salt, I have purposely overlooked one natural factor concerned in its formation, namely, chemical agency. Though very doubtful about the production of common salt, on a large scale, in any other way than as a derivative of the great primeval source, the sea, I will here glance at what is put forward on the subject.

Common salt is said to occur here and there, at rare intervals on the earth's surface, as an efflorescence or in brine springs, *in no way related to rock salt or the sea;* in situations, in fact, in which no common salt could be expected on any theory previously referred to in this work. Such deposits are said to exist largely in Chili; and their formation has been studied by M. Pissis, who has drawn up a report on the subject for the Chilian Government. At the base of the Shevaroy Hills, in the centre of the South Indian peninsula, a salt spring or salt lick, used by cattle, exists, whose presence has been accounted for by chemical action. The whole district is a mass of hornblende, quartz, and felspar, shot with trap. M. Pissis states that the salt is associated with large quantities

of potassium nitrate, which is not found in marine formations, and there is an entire absence of stratified rocks, which are found associated with ordinary rock-salt. The salt deposits are on the surface of the hill plateau (the Cordillera of Maricunga), at various elevations up to 13,200 feet, but not in the valley beneath. Marine shells are quite absent from this deposit. He argues that the salt must have some independent local origin. Besides sodium chloride and potassium nitrate, calcium sulphate and sodium sulphate are, however, largely present.

For the manufacture of the above salts in nature's laboratory, sodium and calcium, nitric, hydrochloric and sulphuric acids, are required. The surrounding rocks are felspathic, and the soil is a felspathic detritus. The felspaths are composed of albite, labrodite, and oligoklase. Labrodite contains a large quantity of lime; albite from 8 to 10 per cent. of soda; oligoklase contains both potash and soda—here are the bases. The same rocks furnish some of the required acids. They contain pyrites, which may yield sulphuric acid on oxidation, and trachytes, which furnish chlorine and chlorides. The atmosphere yields nitric acid. The experiments of Chlöes prove that nitric acid is formed by the action of alkaline carbonates in the presence of oxidizable matter. M. Pissis believes that all the decompositions and recompositions required, resulting in the ultimate formation of the salts actually found, are constantly going on; and are sufficient to account for the existing salt and other deposits.

The deposits referred to are found as follows: on the surface, sand, clay, porphyritic and quartzite stones; next, a firmer layer of conglomerated gypsum and salt; next, sulphites mixed with potassium nitrate, sodium chloride, sodium iodide, potassium sulphate, and sodium sulphate; lower still,

pure sodium chloride and clay, resting on porphyry and granite. Whatever the mode of origin of these salts, it is at least curious that they should be, with the exception of potassium nitrate, a salt easily formed in nature, just such as characterise marine deposits. In the presence of large deposits of gypsum, common, and other marine salts, apparently in a stratified condition, it is difficult to exclude the possibility of a marine origin. Potassium nitrate, or saltpetre, is found associated with common salt in many of the inland plains of Southern India. The salts are extracted together from saline earth by lixiviation, and are afterwards separated by evaporation; having different degrees of solubility. The potash salt is in excess, and is manufactured on a large scale; common salt appearing as a bye product, in the proportion of 30 parts, for every 100 parts of saltpetre. M. Pissis would possibly consider this, also, as another example of the chemical formation of common salt; but no such explanation is needed to account for its presence. We have seen that potassium salts are thrown down by sea water, at the conclusion of its evaporation. At page 46, we see kieserite, carnalite, and kanite, all potassium compounds, associated with the Ascherslefen salt deposit. They are found near the surface, as they should be. The conversion of any of these salts into nitrates by the action of ammonia resulting from the decomposition of animal matter, is a question of time. Professor Kuhlman found that all vapours of nitrogen, including ammonia, mixed with air in spongy platinum, changed into nitric acid or peroxide of nitrogen. (Liebig's Annalen, v. 29, p. 272). In some countries nitrate of potash is prepared from wood ashes by the action of nitric acid, naturally formed, in manure heaps, called "nitre beds." In the Indan plains, above referred to, we have all the conditions requisite for this process, supposing an original marine

deposit. The excess of the nitrate over common salt is no great difficulty when we consider the decompositions which the latter undergoes in calcareous soils. Besides, in some districts the proportion of common salt is altered. In Kurnool it equals saltpetre in amount; in Bellary it more than doubles it; 83 parts of common salt being found, on an average, for 38 parts of potassium nitrate. Time works wonderful changes with the earth's strata, and especially with loose soluble deposits. They are carried about in solution and such of them as do not reach the sea, are deposited here and there in different proportions. We see this also in the case of sodium sulphate, another marine salt, largely found in India. At a place called Mallowna, an inland town in the North of India, salt was manufactured under the orders of English Government up to the year 1871. After that year, the works were abandoned, as they did not pay. The peculiarity of this manufacture was that brine, obtained from brine wells, and highly impregnated with sodium sulphate, was thrown on mounds of earth. It was found that common salt, after a time, effloresced upon the surface of the mound, whereas sodium sulphate was retained. The surface of the mound was then scraped off, and a species of earth salt was made from its lixiviation and evaporation. At Allygurh and Cawnpore, also in the interior of Northern India, where the manufacture of sodium sulphate, or Glauber's salt, has been long systematically practised, large amounts of common salt are produced. In this case, sodium chloride is educed as a *bye-product,* in the process of extracting sodium sulphate from saline earth. As some common salt made in this way escapes taxation, the Government of India were lately endeavouring to suppress the manufacture. The ruling authorities, at present, however, are very properly in favour of fostering and extending all forms of indige-

nous enterprise, and will hardly stamp out the native manufacture of saltpetre and soda, for the sake of stopping small leaks in the salt tax. Saltpetre is a much more valuable mineral than common salt, and it is a "necessary" of the country, which will have to be imported if not manufactured on the spot. After all, as in any given locality the proportions of common salt and saltpetre in the soil are nearly constant, it is very easy to impose a royalty on the manufacture, which will almost exactly cover the loss of tax on the common salt. The manufacturer can then dispose of the latter, and recoup his extra expense.

Ice salt.—This is the least spontaneous of the salts mentioned in this chapter; nor is the salt itself at any time frozen; the name, "ice salt," is intended only to distinguish it from the other members of the series.

When salt water is frozen, the ice, in crystallizing, squeezes out, as it were, the salts which it holds in solution. Lieut. Weyprecht, of the Austro-Hungarian Arctic expedition, (1872-74,) noticed that the surface of salt water ice, on which no snow had fallen, was so soft that the foot sank in it as in melting snow. He observed this also at a temperature of—40° C. He found that this slush was composed of the salts of sea water expressed by the sea in the act of freezing.

Unfortunately, freezing water does not part with all its salts, nor with organic pollution. It has been known to carry crystallized contagia; and sea water ice, when melted, makes a disagreeable potation. It contains but 0·5 grammes of salt per litre, but magnesium chloride is in sufficient quantity to impart a bitter taste. Captain Markham, ("The Great Frozen Sea") more than once refers to the accidental use of salt water ice in the pot, "as causing much annoyance to the sledging parties." The same author states that by exposing "salt junk" at a temperature of—40° F. it is

rendered more palatable, as some of the salt is frozen out of it.

It requires a harder frost to form ice with sea water, than with fresh water. Sea water freezes at about 28° F. or four degrees below the freezing point of fresh water. It is more difficult to freeze, for the same reason that it is more difficult to evaporate, because the soluble salts in solution exercise a powerful natural attraction upon their solvent water, and oppose the disintegrating forces of ice crystallization and evaporation. As saturated brine is four times more difficult to evaporate than sea water, so it requires four times or rather more than four times the amount of frost, to freeze it.

In some parts of Northern Russia, advantage is taken of the severity of the winter frosts to obtain in this way a strong brine of common salt. Sea water is exposed in shallow reservoirs. In winter time the great bulk of the fluid separates and solidifies as pure ice, leaving only a strong brine of common and magnesium salts behind. This brine is necessarily very impure, much more so than the ordinary brine of sea salt culture; for at low temperatures, common salt and magnesium sulphate break up into magnesium chloride and sodium sulphate, so that, although, the process of salt manufacture is considerably abridged by frost, it is likewise injuriously affected. From this brine, common salt is obtained by careful boiling. The boiling process is not pushed far, to avoid as much as possible the residual salts.

As a general rule, unless lime is used in the process, the salt thus formed is very inferior. Sometimes, a second or third charge of brine is added and boiled. The following analyses of ice formed salts, from the undermentioned Russian districts, show a marked peculiarity, in the constant presence of aluminium chloride in large quantities. These are the

only analyses of sea salt in which that mineral occurs. It is probably derived from the pans in which the brine is boiled.

Ice Salt analyses.

	Irkowtsk.	Selenguisk.	Oustkontsk.	Okhotsk. 1st Crystallization.	Okhotsk. 2nd Crystallization.	Okhotsk. 3rd Crystallization.
Sodium chloride	91·5	74·7	76·3	86·0	77·6	79·1
Aluminium ,, ...	2·6	6·5	1·2	3·6	6·2	7·8
Calcium ,, ...	1·1	1·4	3·8	0·9	0·9	0·7
Magnesium ,, ...	2·0	3·6	3·6	2·0	1·7	0·8
Sodium sulphate	2·8	13·8	12·6	7·5	13·6	11·6
Calcium ,, ...	......	......	2·5	4	......	......
Analyst, M. Hess	......	100·0	100·0	100·0	100·0	100·0

Judging from the above analyses, it would seem probable that lime was used in the outturn of the Irkowtsk, and first crystallization Okhotsk, salt samples.

Lime is used for the double purpose of getting rid of magnesium chloride, and of restoring to the brine the common salt which has been converted into sodium sulphate. If an equivalent quantity of quicklime to the magnesium chloride contained in the brine, is added to the brine, the following decompositions take place. The lime seizes on the chlorine of the magnesium chloride, and forms calcium chloride, and precipitates the magnesium as magnesium oxide, as follows:—$CaOH_2O + MgCl_2 = CaCl_2 + MgO + H_2O$. The calcium chloride in its turn re-acts upon the sodium sulphate, and both salts break up and reform as sodium chloride and calcium sulphate; and as the latter is insoluble in strong brine, it is precipitated at once. The following is the formula of this second double decomposi-

tion. $CaCl_2 + Na_2SO_4 = 2\ NaCl + CaSO_4$. Calcium sulphate, owing to its early deposition, is not in the brine which is boiled, and consequently does not form an impurity of the salt. This method of clarifying strong Mother-liquor is applicable in all manufactories in which cold has deteriorated the brine, and produced sodium sulphate. But even if no sodium sulphate be present, calcium oxide will break up magnesium chloride and precipitate magnesium; thus rendering a great service to common salt manufacture, and adding a new and valuable product to the residual salts.

CHAPTER XVI.

THE SALT TAX.

The salt tax is one of the oldest methods of getting a public revenue known to civilized States. It has two great apparent advantages. In theory, at least, it reaches every member of the community liable to pay taxes. And spread over *a large population,* it yields a considerable revenue without pressing heavily upon any one. As one of the earliest common necessities of the people, it came to be one of the earliest taxed to make a public revenue. The Egyptian Priests of Hammomem paid a tribute of the finest rock-salt, packed in palm leaf baskets, to the Kings. (Arrian Anabasis, iii, 3, 4.) The Jews, when they lost their independence, paid a salt tribute. Josephus relates that Demetrius Nikator, writing to the Maccabean Jonathan, 146, B.C., released the Jews from the salt tribute. (Maccab. Cap. x, 29.) We hear of a Syrian salt tax in the time of Alexander the Great, 160, B.C. A salt tribute was imposed upon the one-eyed King Antigonus by Lysimachus, one of Alexander the Great's Generals. (Athen Deipn, liii, c. 3.) Pliny mentions that the King Buckh—probably a Persian—had a greater tribute of salt paid from India, than of gold or precious stones (A.D., 70, circa.) With the Greeks, salt was untaxed, as far as we know. The Romans, however, made great use of salt taxation. At the beginning of the 2nd Punic War, 215, B.C., a tax was levied on salt which gained

for its authors the nickname of *salinators*. Ancus Martius, instituted the *Salinarum Vectigal*, 640, B.C. This is the first record of a salt tax. The pecuniary result was small at first, but at the fall of the republic it was one of the chief sources of revenue. It was a Roman custom to make distributions of salt to the people to calm popular discontent. (Livy. i, 33, ii, 9; xxix, 37.)

In more civilized times the salt tax became almost universal in its application in European countries. From the beginning of the 12th century, records exist of the salt tax in France. In Hungary salt was taxed from the 13th century. In Germany also the tax existed in the 13th century. In Russia it dates from the time of Peter the Great. (Schleiden, Das Salz., pp. 378,379.) In England the tax was re-introduced by William of Orange, 1694. At the present day the only countries untaxed are England (1828), Norway (1844), and Portugal (1846), and these, as we see, have been freed within the last half century.

We have seen (p. 18) how salt has given rise to wars. There is also an instance on record of the salt tax having influenced the fortunes of war. It is said that Napoleon Bonaparte abolished the turnpike dues and imposed a tax on salt instead, to enable him to complete his invasion of Italy by the Simplon. As Hanibal is said to have crossed the Alps by the aid of vinegar, so Bonaparte crossed with the aid of salt.

The salt tax may be levied on the excise system; or it may take the form of a Government monopoly. The latter is the oldest method, and taking one country with another, still the commonest. The tax had its origin in abuse of trade. Originally salt production was in private hands, and the price was kept up unduly by an understanding, or "syndicate" as it is now called, amongst the proprietors.

The Romans, 506, B.C. created what is called a Government salt monopoly with the object of cheapening the salt to the people. (Dr. Schmidt, Das Salz, p. 92). A salt monopoly differs from a salt tax, as it takes into the hands of the state the manufacture and sale of salt. A monopoly is generally considered bad, now-a-days, because Government undertakes duties that would be better discharged in private hands. The prime cost of salt is always high under official management; and it is raised at the expense of the people; whilst the revenue is taxed with the support of the necessary staff of monopoly officials. The monopoly has been abolished in Prussia since 1867. Before the monopoly, the cost of salt at the mines was 4·27 per cent. of the revenue; and after, in 1872, it fell to 0·58 per cent. showing that the working was more economic in private hands. The revenue also increased from 1867 to 1871, from 6,750,000 thalers to 7,750,000 thalers, with a gain to the people in the price of salt. The experience of Prussia is that the manufacture and sale of salt, in commercial hands, both cheapens the produce, increases the quantity of salt used, and extends the area of its distribution. Some other defects of the monopoly system will be noticed presently.

It is claimed for the excise that it is a much less troublesome revenue machine to work, than the monopoly. That without enhancing the selling price of salt, a larger profit to the State can be made out of it. That the self-interests of the merchants engaged in the salt trade would place a more effectual check on smuggling, etc., than at present exists. That a better article would be supplied to consumers. That, as regards British India, free trade in salt, once established, reciprocal benefits would accrue to English and Indian commerce. That the natives engaged in salt manufacture would turn their labour to more

profitable account; and that their moral tone would be elevated.

Many writers, however, object to the salt tax altogether; and it has been bitterly opposed, at intervals, in the past, in England, and on the continent. It is difficult to understand the matter clearly unless we take into account the motives which underlie the peculiar zeal of writers on the salt tax. The opponents of the salt tax are generally interested in the salt trade, either as manufacturers or merchants, and these, like Lord Dundonald, (author of The Present State of Salt, *etc.*) attribute to salt many and rare virtues. The defenders of the tax, on the other hand, are often open to the suspicion of Government inspiration. It is their cue to disparage the value of salt in hygiene, agriculture, etc., whilst insisting on the propriety of taxing it. Occasionally the salt tax has formed the centre around which political battles have been fought. At the first French Revolution it was made a tool of by agitators, who had very deep purposes in view. I am not aware of a single author who has written a book in favour of the tax. All the authorities mentioned in the Bibliography are against it. But, essays in favour of the tax are common enough in fugitive literature. The strongest arguments against the tax go to show that it is not the outcome of a deliberate peace financial policy. It has always been adopted as a temporary measure; to meet a pressing deficit; or as a war tax. And, moreover, it is an inelastic source of revenue. No increase of income can be got from a salt tax, once it has reached the limits of the people and their wants: that is from the time that it has been got into thorough working order. These limits the tax itself tends powerfully to contract. Increasing the amount of the tax, to squeeze more out of it, involves various dangers to the State; and cannot be taken into serious consideration,

after the tax has been once established on a sound financial basis.

From the fact of its having undergone many changes in its salt laws, England affords an excellent field for the study of this question. We have seen that the tax was first imposed upon the country by the Romans, as early as 640, B.C. In later times it was re-introduced by William of Orange, in the year 1694, to the extent of a shilling in the bushel, which amount was rapidly increased till 1729, when the tax was again abolished. It was reimposed by Sir R. Walpole in 1732. In 1798 the duty amounted to 10 shillings a bushel; and in 1805 to 15 shillings. In 1823 it was reduced to 2 shillings a bushel; and in 1825 it was abolished altogether, as the result of agitation and parliamentary pressure.

Agitation against the salt tax began to manifest itself by pamphlets and petitions to Parliament about the end of the 18th century, when the duty on salt amounted to 10 shillings a bushel of 56 lbs. A Committee of the House of Commons sat in 1801 to inquire into the salt laws. This Committee, came to the following resolution which was submitted to the House. "*Resolved*, That it is the opinion of this Committee, that a commutation of the duties on salt would be productive of many great and important advantages to all descriptions of persons in this kingdom, and would be highly beneficial to its agriculture, fisheries, trade, and manufactures."

Manifestations of hostility were redoubled in the beginning of the present century when the tax was raised to 15 shillings a bushel. Sir T. Bernard, and Samuel Parkes, a Chemist, being the principal pamphleteers. A Parliamentary Committee was then appointed to investigate the question, and it held its sittings in 1818. A great number of people of all kinds were brought to interrogation before the Committee. The weight of evidence afforded was in favour

of the repeal of the duty, from which measure they anticipated the most satisfactory results to trade, agriculture, commerce, etc., (See Parl. Papers. Report the third, from the Select Committee on the Laws Relating to the Salt Duties, 1st June 1818, Vol. 5.) The result of the report of this Committee was the reduction of the salt duty to 2 shillings per bushel in 1823, and shortly afterwards, in 1825, the repeal of the salt laws. What has been the effect of this legislation? Some writers pointing to the grand development of chemical manufactures, which dates from the repeal of the tax, say that it has been a great success. Russia appears to be of this opinion, for Count Loris Melikoff abolished the tax in that country in 1880; but there, again, "Nihilist" agitation was at work, to complicate the question. Dr. John Yanjool, Professor of Political Economy, University of Moscow, has written on this subject. He came over to England, especially to study this question in the latter part of 1880, and devoted many months to it. His work, "The History of the Repeal of the Salt Duties in England and its Results" has not been published, as yet: but from an English abstract of it which he was kind enough to give me, I gather that he finds as the result of his investigations, that the repeal of the salt laws in England disappointed the hopes of its promoters in almost every direction save one, and that is as regards chemical manufacture. He found that the cheapening of salt did not take place to the extent to be expected from the abolition of a duty thirty times the proper value of the article. And that the production and trade of salt, though greatly increased, could not compare with the expansion of the coal and iron trade in the same period. The development of railways in a great measure accounts for this, however, as the rails gave employment to coal and iron, whilst by shortening time and space they did away with the

necessity for salt food. He allows a great increase in the herring fishery: and hopes for a great revival of chemical manufactures in all its branches in Russia, as a consequence of the abolition of the tax in that country. The Professor apparently favours the abolition of the tax; but his labours in English History make him far from enthusiastic as to the benefits to be expected from the measure. It may be added that in his own country the abolition of the tax had not a commensurate effect upon the price of salt. It was not cheapened more than 10 kopeks per pood, though 30 kopeks a pood had been taken off with the tax.

I will now examine the objections to the salt tax in detail, and see how far the tax can be justified. To do this with point, the tax must be viewed with reference to some country in which it exists in an objectionable form: British India will answer the purpose. Over a great portion of that Empire, a salt monopoly exists, and salt is everywhere taxed at the rate of Rupees 2 a maund of $82\frac{2}{7}$ lbs. Taking the average value of the rupee at one shilling and eight pence, this is equivalent to a tax of about 2*s*. a bushel of 56 lbs. Compared with other countries this tax, although ten times the value of the article, is light. It is the reduced tax employed in England in 1823, as the result of the labours of a Parliamentary Commission.

The first and most serious charge brought against the tax is that it is cruel and oppressive in its action upon the lowest class of the population. It enhances the price of salt, and consequently stints the people in the use of an article which is essential to their well being. Viewing salt from the physiological and hygienic stand point taken up in this work, it will be readily admitted that this objection to the tax is a very strong one, if it can be proved that the poor are deprived of sufficient salt, or made to pay unduly for it. It is

difficult to compute how much salt, in point of fact, is consumed per head, by the labouring classes.

Perhaps the best way to solve the problem, is to take the quantity of salt which the people require, and should have, and calculate the tax upon it. Dr. H. King, M.A., author of a valuable work on hygiene, Madras 1880, says of salt, "100 grains are perhaps sufficient in jails, where the staple food is wheaten flour, while at least twice this quantity will be required with a rice diet" per diem. The reason of this is because rice is a food almost devoid of salt. The maximum amount of salt essential to the welfare of the people has to be computed for, when they live on rice.

This allowance appears to mark the bare physiological necessity of the case. It is much less than that issued to soldiers and sailors of every nationality. And what is more to the point it is less than the Government issue to the natives confined in Indian jails. The jail ration of salt is the lowest amount thought to be compatible with health. It is never less than ½ an oz., or 218 grains, and is commonly as much as 437 grains. I should be inclined to consider 250 grains of salt per diem a fair hygienic allowance, and will compute it at that amount. But it must be borne in mind that this refers to rice eaters and adults only. Some deduction must be made on account of the infant population, if we wish to calculate the amount of salt required per head by the whole population of a country, allowing for all ages. We may safely take 200 grains as being the average amount required, as the error, if any, will be on the side of excess. In round numbers 10 lbs. of salt per head per annum will satisfy the wants of the poor.

From this quantity a further deduction has to be made on account of salt consumed, other than taxed salt. Salt for fish curing is untaxed, and as the poor get their supply of

animal food chiefly from salt fish, they do not need to buy 10 lbs. of salt. It is probable that if salt fish were as cheap and common as they should be in a maritime country, 8 lbs. of taxed salt would amply suffice. But, having taken British India in illustration, I must neglect these facts altogether, since the quantity of salt fish consumed there is almost inappreciable. This, however, is not a normal, but an abnormal feature of the tax, which can have nothing more than a local significance. *Per contra*, enormous quantities of contraband salt are consumed in British India; so that the amount of taxed salt required is brought even below what it would be with a liberal salt fish diet. This can hardly be considered an unusual feature of salt taxation, however irregular in appearance, for a contraband trade in salt always flourishes side by side with the tax. The thing is impossible to avoid, with an article so freely distributed in nature as salt. It is an awkward fact which has to be considered in calculating a salt revenue, and which cannot therefore be left out of account here. One way or the other, with salt fish or with illicit salt, or with both together, the poor may get 20 per cent. of their salt free of taxation, and 8 lbs. per head per annum is perhaps the most that they need buy.

It is not the case, however, that the entire population gets a fair allowance of duty free salt. Hundreds of thousands, who are favourably situated as regards spontaneous salt, get more than their share; whilst a still larger number get none at all. It is the case of these latter we must keep before us when considering the condition of the poor affected by a salt tax; for the grievance is, that some suffer unduly to make a public revenue. If the Indian poor buy 10 lbs. of taxed salt per annum, they will have to pay for it less than 5*d.* in the shape of taxation. It amounts to a poll tax of 5*d.* per head per annum. And this is about the

worst that can be said of the tax in its relation to the poor.

One way of stating this objection to the tax, common with its thick and thin opponents, is to take the consumption per head of the population as found in statistical tables, which varies from 8½ lbs. in Switzerland to 40 lbs. in England, and to credit the poor individually with the consumption of that amount. Arguing from these premises the Germans, for example, are said to consume 15 lbs. of salt per head, per annum, (Schmidt and Schleiden)—whereas the tables include salt used up in the arts, in agriculture, etc., with which the poor have nothing to do. These statistical tables are formed by spreading over the entire population the whole amount of salt used up in the country; and in every country, however backward in the arts and agriculture, large quantities of salt are taken by cattle, horses, sheep, etc. Statistical tables are, in this connection, entirely misleading. Schaefer goes the length of assuming 19 lbs., per head, as the poor allowance of salt! It is but fair to note, too, that in *meat-eating countries*, it is doubtful whether the poor require more than 10 lbs. of salt, on physiological grounds; so that when we find them credited with eating much more than that amount, we may suspect bias, and be sure that industrial activity, not poverty, is in question. Another way of stating the objection, with prejudice, is to make a comparison between the rich and the poor, as to the relative amount of the income of each spent upon salt. Thus a Hindoo labourer gets about 48 rupees, or 84 shillings a year, as wages; with 5 in family, he uses 50 lbs. of salt, on which he should pay a tax of 2 shillings, or about 2·4 per cent. of his income. A man twice as rich, pays half as much per cent., under the same conditions. And a wealthy man pays an incalculably small percentage. Work-

ing the percentage on income, in this way, it will be found easily, that the richer the individual, the less per cent. of his income he pays for salt for family use: therefore "the poor are infamously plundered"! (*Schleiden, Das Salz*, p. 223.)

To emphasise the pressure of the salt tax, the poor are also represented as having large families. Schaefer takes a family of eleven as the basis of calculation: but this in reality overshoots the mark. In such a family there are several bread winners, and to compute the expenditure on salt as a percentage on the father's income, only, would be manifestly unfair. I have taken a family of five, as probably the worst case; but even in that case, some addition to income should be made on account of the wife's earnings. The wife in India generally earns nearly as much as the husband.

I have made many enquiries from the poor inmates of Indian Jails and Hospitals, as to the amount of salt they use with food at home, and have satisfied myself that even the poorest use salt without stint. There is clearly no deprivation; they speak decidedly on that point. But it is not so easy to distinguish the exact weight of salt consumed per head, since salt is sold by measure in the bazaars of India; and the people buy only a small supply at a time. Nevertheless, I have ascertained that a family of five consume *over* 50 lbs. of salt per annum; 60 lbs. would be perhaps under the mark; and that the actual consumption per head is over half an ounce a day. This makes the payment of the tax a little greater, say half a crown a year, instead of two shillings. On the other hand I have not met with a single family of five, connected with the labouring classes, in Jail or Hospital, who could not muster more than Rs. 48 per annum income between them. The incomes varied from Rs. 60 to Rs. 100 and Rs. 80 would be about the average. Hence

though the poll-tax is greater than stated, the ability to bear it is greater also.

It appears, therefore, that the pressure of the salt tax upon the poor, *theoretically considered,* on the basis of their absolute wants, amounts to the same thing as a poll tax of 5*d.* per head. And that *direct enquiries* amongst the poor show this to be an underestimate, by about one penny. We have now the population census and the revenue returns with which to compare these estimates.

The population at the last census (1880) was over 250,000,000. The number liable to the salt tax, about 200,000,000. A six-penny poll tax on that population would yield £5,000,000. But the revenue was much better than that. It amounted to about £7,000,000. This, however, does not prove a larger consumption of salt by the poor, for two reasons: First, the salt tax in 1880, and up to the current year 1882, was 20 per cent. higher in some parts of the country and 30 per cent. higher in others, than at present. Second, the revenue includes the tax on agricultural and industrial salt, which, considering the immense number of cattle, horses, and sheep, in the length and breadth of India, and the extent of the tanning industry, must amount to a considerable sum. The fact is the revenue should have been considerably over £7,000,000. If a census of live stock existed the amount could be estimated with some approach to accuracy. The difference between the estimated and actual amounts would then afford a fair measure of the value of the contraband trade. Various authorities have set down the pressure of the salt tax upon the poor in India, as being equivalent to a poll tax of from 7*d.* to 10*d.*; but as these estimates were made during the higher rate of taxation, and were based as usual upon the two factors, revenue and population, only, and with reference to divers

rates of exchange, they need not be further noticed here.

The remission of taxation took place during the current year, 1882. So far there is not time to observe its effect upon the revenue; but in the long run it will probably yield more than the heavier tax. A tax which would have been light in any other country, was probably too heavy for British India, whose labouring millions carry on an unceasing struggle with impending famine. They will now use salt more freely for their cattle, which sadly need it; and though those who live near salt deposits, will continue to use them, legitimate trade will expand at the expense of the contraband trade, and the consumption of revenue-producing salt will increase elsewhere, in all likelihood. With a light tax, contraband trade is severely handicapped; for it is debarred the use of railways, and public roads, and frequent seizures equalize the profits.

The experience of France teaches us that beyond a certain point, taxation and consumption of taxed salt bear an inverse proportion to each other. In the time of Neckar, 1789, with the *grand* Gabelle at 1 fr. 24 c. the kilo, the consumption per head stood at 4·6 kilos; with the *petite* Gabelle at 67 c. the consumption was 5·9 kilos. In 1790 the *legal price* was fixed at 30 cents the kilo, and the consumption increased to 8 kilos per head. In 1793, the duty being abolished, the price fell to 20 cents and the consumption rose to 10 kilos per head per annum. So it remained till 1806, when Napoleon put on a tax of 20 cents. a kilo, and the consumption fell to 6·6 kilos. By the end of 1812 the consumption stood at 7·4 kilos. At the end of 1813 a further tax of 20 cents. was imposed and the consumption fell to 3·5 kilos. In 1814 ten cents. were taken off the tax and the consumption rose to 5·3 kilos. In 1848 the consumption had further increased to 6·4

kilos. In that year the tax was reduced from 30 cents. to 10 cents. the kilo, and the consumption rose in 1849 to 9 kilos.

In Prussia, in 1842, the tax was reduced from 15 thalers, to 12 thalers the ton; the consumption increased at once, and the revenue the following year rose from 55,872 to 67,667 thalers.

At the present time, the consumption of salt as taken from official statistics, stands in the different countries, below mentioned, as follows:—England, 40 lbs.; Portugal, 35 lbs.; Italy, 20 lbs.; France, 18 lbs.; Russia, 18 lbs.; Belgium, 16½ lbs.; Austria, 16 lbs.; Prussia, 14 lbs.; Spain, 12 lbs.; British India, 12 lbs.; Holland, 11½ lbs.; Sweden and Norway, 9½ lbs.; (Schleiden) Switzerland, 8½ lbs. England and Portugal, which are untaxed, lead the way; but Norway, which is also untaxed, lags far behind. Assuming that the people only require 10 lbs. per head of taxed salt for their own use, everything above that represents so much industrial activity. England does not lead the way by reason of its freedom from taxation, but by reason of its great industrial resources, which would still keep it in the front rank under any ordinary pressure of taxation.

The above table, it may be noticed, in passing, seems to show that the population of countries, weighted with a salt tax, use salt in much larger quantities than is necessary for health. This does not bear out the conclusion that the tax deprives them of salt.

To return to the natives of British India. A rice-eating family of five—that is a typically destitute family, in its most dependant state—consumes 60 lbs. of salt per annum, on which the tax amounts to 2*s*. 1⅓*d*., or 3 per cent. of income. Theoretically this seems a great deal: but, viewed in another way, it is only 2¼*d*. a month, which can scarcely be called oppressive!

Our knowledge of this subject will not be complete without a review of some other factors concerned in regulating the price of salt. First with regard to distribution charges. The advocates of the tax state that the price of untaxed salt varies with distance from its source, and the means of communication, in a much greater degree than taxed salt, and that a light tax tends to steady the price. The effect of speculation upon untaxed salt is also noticed. It is said that the removal of all Government interference causes a great irregularity in the price of salt at its source, and that the ultimate result is the creation of a virtual salt monopoly in the hands of a few wealthy capitalists, fortunately situated as regards salt sources and railway lines. Roman history furnishes an example of this kind, already noticed. But the matter may be more clearly seen in the fluctuations of the price of common salt in England, after the removal of the tax. From 1845 to 1850 the average price of common salt at the works, in England, was 7*s*. 6*d*. per ton. The lowest price was 5*s*. 3*d*. and the highest 12*s*. per ton. In the next decade the price varied also between 5*s*. and 12*s*. per ton. During the American war prices fell to an average of 4*s*. 6*d*. the ton; some lots were sold as low as 3*s*. 9*d*. the lowest price ever known. In 1865 the price again advanced, and in 1872 reached 20*s*. per ton. In 1873 it began at 12*s*. and rose to 15*s*. per ton. In 1874 it varied between 15*s*. and 20*s*. per ton. The "Public Ledger" gives the price of common salt-cake of late years, as follows: 1875-76, price 25*s*. a ton; 1877, price 25*s*. to 30*s*; 1878, price 22*s*. to 25*s*; 1879, price 20*s*. to 22*s*. per ton. It should be observed that the price of salt in England is affected by the price of coal, since it is all boiled salt. The experience of Russia, since the abolition of the tax, points also to the conclusion that speculation affects the price of salt in a greater degree than taxa-

tion. As we have already seen, the complete abolition of the tax, in Russia, did not benefit the consumer, in a corresponding degree. Two-thirds of the tax struck off by law, remained in the price of salt; and the merchants and middle men profited at the public expense. It should not be forgotten that the salt revenue is a public revenue, laid out to public advantage, like any other. It is not to the interest of the poor to abolish it, to the enrichment of the salt trade, unless in return the price of salt is brought down proportionately to the remission of taxation, which does not appear to be usually the case.

There is a fallacy however underlying this line of argument, for although it is perfectly true that the price of *untaxed* salt varies at its source, from time to time, as much as 400 per cent.; and that distribution charges treble and quadruple its first cost; still, this is precisely because untaxed salt is so cheap. Its prime cost varies from 5 to 20 shillings a ton, which is in fact 400 per cent. Put on a tax of 2 shillings a bushel and the fluctuations are thereby reduced from 85 to 100 shillings a ton, or about 15 per cent. instead of 400 per cent. It is the same rise, actually, but not relatively. But this is far from benefiting the consumer, who has to pay at least 400 per cent. more than the highest untaxed price, for the sake of steadying the market. Again, salt at 10 shillings a ton, will be doubled in price by a journey, which would only add 10 shillings on to the price of salt at 90 shillings: the difference in the first case is 100 per cent. and in the second 9 per cent; but there is no advantage in that to the man who pays 80 shillings extra for the salt. This argument is in reality more in favour of the repeal, than of the tax. It is very doubtful whether, in point of fact, the existence of a salt tax would prevent the fluctuations in the price of Cheshire salt, extending to the

limits of 15 or 20 shillings per ton. And as regards its retail price, at some distance from its source, it confers no real advantage. At Chittoor, about 100 miles from Madras, the source of supply, bay salt, which costs Rs. 2 a maund at Madras, is sold, retail, at about Rs. 6 per maund; so that even monopoly salt can claim no advantage as regards steadiness of price in transit.

A second count of the first indictment is that the poor from being stinted in the use of salt are physically deteriorated. If physical deterioration could be proved and traced to the want of salt it would settle the question. But the statement is made simply as a corallary to the first proposition that the poor are stinted, and no proof of the fact is offered. Attention has often been drawn to outbreaks of sickness supposed to be due to the use of Government salt of bad quality; but never to debility, traced to the want of salt. If such cases actually existed, and in a much greater degree if they were prevalent, they would be quoted and established as facts. That they are not so, is a sign of weakness in the cause. In my experience of India, extending to 14 years, I have not met with a single instance in point. On the other hand I have noticed as a suspicious circumstance that a large number of the poorest class of natives, inmates of the public hospitals, are infested with round worms. To a charge of this kind the advocates of the tax reply, *quod gratis asseretur, gratis negatur*; and there is nothing more to be said about it. There is no proof that the poor are deprived of salt; and it does not appear that they pay unduly for it.

A second objection commonly taken to the salt-tax is that it is a bar to scientific farming, the back bone of a nation's strength. This is the chief consideration that led to the overthrow of the salt duties in England, in 1825.

Although facilities were afforded for the use of salt, free of duty, for agricultural purposes, it was felt that the tax operated as a restriction upon the use of chemical manures; and the most sanguine expectations were formed in regard to farming prospects, from its repeal. These expectations we know have not been realised. On the contrary the use of salt in farming has diminished in England since the agitation for the repeal, with its frequent pamphlets on the benefits of salt to agriculture. No one is interested in the question now; and since the days of Johnson's "Essays on Salt," Falk's pamphlet, 20 years ago, (1863) is the only publication which has revived the subject.

There is no question here, however, as to the value of salt in agriculture. Sufficient evidence of its fertilizing powers, under certain conditions, and of its value to live stock, has been furnished in the appropriate chapter. The question is, is the *complete abolition* of the tax necessary in the interests of agriculture? This question should be considered in the light of this fact, that free salt for agriculture is a recognized provision of salt taxation in all civilized countries. In France, Belgium, and Prussia—as formerly in England and Russia—such salt is untaxed. How far then will farming benefit by the removal of *all restrictions* on its use.

The experience of England and of Russia teaches us that the repeal of salt duties is not followed by any increased use of salt in agriculture. In England there is a fashion in manures. In Russia the peasantry are too poor to avail themselves of salt manures, taxed, or untaxed. And the same is true of poor countries generally. With a well administered tax, providing free salt for farming, those who can afford salt manures can have them without stint. The abolition of the tax will not bring such manures within the reach of the poor.

With regard to cattle the case is different. Salt is a necessary portion of their food; and few owners of cattle are so poor as to let them go without it. Whether they get enough salt in taxed countries, notwithstanding the relaxations made in their favour, may be considered very doubtful.

It is unfortunately true that there are countries, in which salt is taxed, without any provision whatever being made for its free use in agriculture, or for cattle. British India is open to this reproach. But this does not affect the question, which refers only to a liberal and statesmanlike tax. No one could argue in favour of a tax which tends directly to impoverish a country, and no such question is raised here. In what way free salt is provided for agriculture usually; and in what way this may be done in India, without loss, I shall endeavour to explain hereafter. As regards loss, however, it should be premised, and it is commonly recognized, that what is lost in salt revenue by the remission of salt duties for agricultural purposes is gained in the increase of revenue from other indirect taxes, consequent on the increased prosperity of the peasantry.

A third charge brought against the salt tax, is that it has a prohibitive effect upon that large class of chemical industries, the alkali manufacture, bleaching powder, soap, glass, hydrochloric acid works, etc., which form the main springs of the wealth of England, and which have their source and origin in cheap salt. This is an objection which tells with great force in countries which have no important indigenous manufactures of their own. And with still greater force in the case of those which have a silver standard of money, as against a gold standard in the commercial centres with which they deal. The balance of trade flowing steadily against them for want of indigenous manufactures, causes

a large depreciation in the value of their silver money. They not only have to import articles which might easily be made at home; but they have to pay an enormously increased price for them.

It will be evident that but few countries lay themselves open to this objection, in its worst form. Indeed, as a general rule, salt for manufacturing purposes is exempted from duty in the administration of salt laws. This was the case in England, and in Russia, during the regime of the salt tax. It is so, at present, in the chief countries of Europe, where salt is taxed. But however careful a Government may be to favour the development of chemical manufactures, all restrictions on taxed salt cannot be removed. Certain irksome formalities have to be complied with, and a strict supervision exercised as to the disposal of the salt. It is this which is said to check the growth of manufacture; and the opponents of the tax point to the rapid development of chemical industries, after the repeal of the salt laws in England, in proof of their contention. I think too much has been made of this point, as the period referred to is that in which the development of steam machinery, railways, and steamers, gave a remarkable impetus to every other industry, as well as to salt. Capitalists will not be deterred from such enterprises by the formalities necessary to obtain duty free salt, when the facilities otherwise promise a good profit. But, at the same time, it must be admitted, that the tax operates as a deterrent, and turns the scale, where the inducements to manufacture are not great.

There is nothing to say in favour of the tax, where it exists in its worst form, as for example, in British India, where manufactures are deficient, chemicals are imported, and salt is not allowed duty free for manufacturing purposes; except that an alteration of the salt laws in favour

of manufacturers would purge the tax in a great measure of its objectionable character.

Some further objections to the salt tax, may be classed together, thus. The thing taxed is such an abundant natural product that it is difficult to prevent smuggling. An expensive revenue and police establishment are required to put down illicit salt traffic. And the poor are demoralised, by the widespread temptation to steal salt! Salt is certainly so widely distributed in nature, and so easily procured, that the poor are sorely tempted to gather it when and where they can. If this only referred to the struggling poor, gathering up salt for household use, who could blame them, or speak of their demoralisation? Such language might suit the salt revenue police; but these are not the views of the free trade school, who would remit the tax. Their objection lies against the smugglers, who undoubtedly drive a profitable wholesale trade in illicit salt, wherever the tax exists. The facts are beyond question. In England, before the abolition of the tax, smuggling on a large scale was common, and serious collisions between salt smugglers and the police were of frequent occurrence. The Chinese salt smugglers employ fleets of five or six armed junks, at a time, to transport salt; and the Chinese Government employs a special fleet of revenue gun boats, to antagonise them; and with indifferent success. In India, the existence of the contraband trade in salt is notorious. The Finance Minister, in the Budget statement for 1880 says, "The reduction of the salt consumption in Madras is more apparent than real, because a large number of the population consume untaxed salt." He blames the law for this, believing that it is either too weak or badly administered. Yet from 2,000 to 3,000 people in India, are annually imprisoned for offences against the salt laws. But the infamous Gabelle salt laws, which

existed in France, before the Revolution, are chiefly relied upon to point the moral of this objection? Even the consumption of salt was enforced under this irrational code. Every one was obliged to take 3 livres 9 sous of salt, a day, from the Royal salt granaries; and families, 19 livres 15 sous a day. The punishments for offences against the salt laws were of the severest kind, as hard labour in the galleys; and the code may be said to have been enforced at the point of the bayonet, and with much bloodshed.

The spectre of the Gabelle, however, need not be imported into this discussion. Nothing of the kind exist at present or, probably, will ever exist again.

It appears, then, that the demoralised poor, who are drawn into crime by the weight of the salt tax, and who merit, consequently, the sympathies of the public, are the unfortunate contrabandists, who are caught passing illegal salt. These are the people who find their way to jail. The others, who take salt for their daily wants, are not often caught, because they do not carry more salt than they can easily conceal about their persons; and when they are caught, they are lightly dealt with. As their salt thefts are only from hand to mouth, they are not the persons pointed at by the anti-tax moralists.

Now as regards the contrabandists; if we discriminate the facts, we find that they are professional criminals. Smugglers are never very nice as to the commodity they deal in; what they look to is the profits of their trade. The Chinese salt smugglers are not held to be innocent of opium. The salt smugglers of England still survive in the tobacco and spirit contraband trades. Take away the salt tax, and these people turn their talents to account in some equally objectionable way, for with them honesty is not the best policy. Many would go so far as to say that they are

unprincipled ruffians, who so far from being contaminated by jail contact with other criminals, are much improved by their residence jail. It is not easy to make a strong point against the tax out of the crime which it is said to occasion, without going back to the Gabelle and its 5,000 annual victims.

Nor is there much force in the objection to the expensive revenue and police establishments required to administer the tax. In England, in the year 1820, the gross revenue from the salt tax amounted to £1,824,570, and the charge for collection to £33,879 or less than 2 per cent. In Russia, in 1878, the gross revenue was 18,225,775 roubles, and all charge of realization amounts to 812,347 roubles, or about $4\frac{1}{2}$ per cent. After the abolition of the monopoly in Prussia, the cost of the salt excise at the mines was 0·58 per cent. of the revenue. These are not high charges, and it is clear from these facts that the salt tax can be administered for about 2 per cent. of the income it brings in, as was formerly the case in England. This is about what an ordinary man of business charges for collecting rents or other similar kinds of private revenue.

Of course, examples of an opposite kind might be cited, where the cost of collecting the tax is disproportionately high. In India it is said to amount to about 13 per cent. on a revenue of £7,000,000; inclusive however of heavy subsidies, amounting together to £323,000, annually, to the French and Portugese Governments, and to Native States, to purchase this non-interference with the monopoly. These payments are included in the cost of collection, since, in their absence, greater vigilance would have to be exercised; though it may be questioned whether at such a price or with such results. By a recent law, 1881, the Goa Government make a gift of 1 lb. of salt a month to the strictly

poor! But whatever the facts may be in particular cases, an expensive and cumbrous establishment does not prove that the tax itself is bad; but that it is badly managed. That this may have been the case, formerly in India, is to be inferred from the following passage in the Budget Statement of the Indian Finance Minister, for 1880. "The Inland Customs Line, on the enormities of which I have so often dilated, finally disappeared at the commencement of the present official year. When I think of this abominable barrier, which was likened to the Great Wall of China, stretching 2,000 miles across the whole of India, so that, if it had been put down in Europe, it would have reached from London to Constantinople, with the countless evils that it entailed, I find it difficult not to begin again my old expressions of indignation. However, it is now dead, and I congratulate Your Excellency and the country on the fact. By its disappearance we have saved about £100,000 a year."

In the fifth place, the salt tax is said to paralyze the trade and manufacture of salt. But there is really no proof of this. The experience of England has shown, and that of Russia, is showing, according to Professor Yanjool, that the removal of the tax causes the concentration of the salt trade in the hands of a few capitalists, who gain a virtual monopoly of salt, which they may, or may not, exercise for their country's good. As struggling traders and manufacturers are driven out of the field, until the monopoly is complete, it is evident that, if we consider the interests of the trade alone, the abolition of the tax does not work in the direction of affording the greatest good to the greatest number.

Sixthly, there is the theoretical objection to the salt tax, that it is wrong to harass the proletarian classes, with a tax upon one of the necessaries of life. It is immoral!

This is undoubtedly an argument of great force where other taxes are available to keep up the financial equilibrium. Where the proletarian classes are civilized and drink duty-paying liquor, or in some other way contribute to balance the revenue and expenditure. But where they do not, and cannot be got at, as in India, for the support of the country, except by taxing an unavoidable necessary, such as salt, the tax is both just and reasonable, unless we suppose that the people should bear no part, whatever, of their country's burthens. Objections of this kind may suit politicians of a certain class: but they are not within the range of practical finance. The revenue, of a country must be raised somehow, and objectors to the salt tax are seldom found prepared with a better method of getting it. The abolition of the tax in England and in Russia counts for nothing as an example to be followed in all cases alike, without regard to local circumstances. Apart from the strong parliamentary and private interests involved in the first case, and the peculiar circumstances which brought Count Loris Melikoff to the front with this measure, in the second, the sacrifice of revenue involved was not in either case great, or even serious, and it was easily made up from other sources. The salt revenue of England, when the tax was abolished in 1825, was only £1,460,631, a sum which could be recouped by the addition of one or two pennies to the income tax. In Russia, the salt revenue, lost by the repeal of taxation, was 11,000,000 roubles or about £1,500,000, and this amount was at once realized, by alteration, in the revenue, introduced by Count Loris Melikoff at the same time that he took off the tax. In other countries it is different. In India with an inelastic revenue derived from three sources, land, opium, and salt; in which the salt tax produces £7,000,000, the case is quite altered.

There is an enormous difference between a *light* salt tax yielding a handsome revenue from a *large* population, and any salt tax yielding a poor revenue from a small population. The cases are not parallel; and the distinction should be insisted upon. In the latter case a poor revenue of a million or two, at most, is extracted from an unwilling people, at a cost of legislation which acts in restraint of fisheries, agriculture and manufactures. The loss and the gain are so evenly balanced that the odium turns the scale against the tax. It is not a wise tax in small countries. But a light tax, proportioned to the resources of the people, is an unobjectionable way of raising revenue in very populous countries, if it be accompanied by facilities for the use of free salt in agriculture, the arts, and the fisheries. It should be remembered that a salt tax, however well arranged, must hamper with regulations, the use of free salt, so that to encourage agriculture, etc., its duty-free provisions should be most liberal and ample.

Lastly, the tax is opposed on the ground that it is an interference with free trade. This objection applies with equal force to taxes on all manner of commodities, as tea, tobacco, coffee, sugar, spirits, &c., and therefore amounts to little more than indication of hostility to taxation in any form.

Having now gone over the objections to the tax, in detail, it will be seen that they depend entirely upon circumstances for their force. In some cases, owing to faulty salt laws, they are very strong; but then it is the management of it, and not the tax itself, which is at fault. There is very little to be said in favour of a salt tax in small communities. There is nothing to be said in favour of a tax which is imposed indiscriminately upon all kinds of salt, and which is unrelieved by any concessions in favour of agriculture, fisheries, manufactures, &c. But on the other hand, a light

salt tax, imposed upon a large people, yielding a big revenue, and fenced round with all the safeguards necessary to protect indigenous industries from ruin, is almost unassailable. Let us see now what are the needful provisions of salt, duty free, which should accompany the tax. Salt for fish curing is perhaps the most important of them. It is an easement to the poor. It increases the food resources of the people; a matter of some moments in countries liable to famine. It is the chief source of nitrogenous food to the poor. It developes fisheries, and the wealth of sea coast towns.

It is worthy of remark that exactly in proportion as a country is backward in facilities for rapid and cheap locomotion, is the use of salt required as a preservative of food. In former days, much larger quantities of salt were used up in the fish and meat curing trades of England, then at the present day, when steam and ice bring fresh provisions within the reach of almost all. Nevertheless, free salt for fish curing is still a great boon, even in the most civilised countries. In England, Ireland, Scotland, and France, for example, the fisheries are seldom so well provided with trains that they can send off large takes of fish to the great markets without delay. But delay with fish means loss. And the loss would be wasteful and ruinous, if it were not for the use of salt. Again, large fishing enterprises are impossible in countries which do not afford abundant facilities for the use of free salt for fish curing. People will not invest capital in fisheries, where adequate means of preserving the fish, when taken, are not at their disposal. In France, large covered buildings, "salting houses," are built on the fishery quays, at which the boats arrive with their takes of fish. In these salt is stored for fish curing; and ranges of slate-tables are provided for the purpose. Sardine boats are allowed to

carry free salt as ballast. India is woefully defficient in this respect, considering the slow means of communication, the poverty of the people, and the nature of their diet. Consequently it has no regular fishing fleets; no large fishing centres; and there appears to be no capital invested in this class of enterprise. Within the last ten years some "curing sheds" have been erected upon the Madras Coast, and at Goolundo, in Bengal, where salt is sold at 7½*d.* per 82 lbs. for fish curing. But with few exceptions these sheds are *at the bay-salt works,* far away from fishing villages and railways, often indeed far from the sea. As a measure for the relief of the poor, or for the encouragement of fisheries, they are very inadequate. As an experiment, they do not fulfil the conditions necessary to success.

In India this measure is still unfortunately looked upon as being in the experimental stage. As late as July 1880, the Government of India asked the Governments of Bombay, Bengal, and Madras for their opinions as to the discontinuance of the relief, on the grounds that it was unsuccessful as an experiment, and detrimental to the revenue. The first two Governments agreed to stop the relief, and the Goolundo depôt was thereupon closed; but the Madras Government wisely inclined rather to extend the facilities, and obtained permission for the continuation of the experiment for another year. It appears from the statistics then published that the total quantity of salt used in fish curing in the Madras Presidency, the best supplied, during the twelve months from June 1878 to June 1879, was 414,792 lbs.; which would give the people of Madras about 70 grains a piece according to the population census of 1871. The expenditure incurred is set down at Rs. 2,775; and the amount realized by Government at Rs. 2,256, leaving a balance of Rs. 519, or about £50, as loss on the experiment. The experiment

is one touching the lives and happiness of the Indian people. As it stands, it might be discontinued without much appreciable suffering, for it is inadequate; but it is to be hoped that it will give place to a wider measure of relief, which will bring the blessing of salt fish home to the bulk of the population. The Madras Government are already extending the number of salt depôts for fish curing; but the latest returns (1882) show that there are only nine fish curing stations in the whole Presidency, which has a coast line exceeding 1100 miles, and a population of about 32,000,000.

Here are some of the enactments formerly regulating this subject in England. By 38 Geo. III., c. 89. S. 40, no duty was payable on salt taken for fish curing. S. 56. Salt for fish curing may be imported. S. 12. Before being delivered duty free, bond in double the amount of duty must be given that the salt shall go to fish curing. The following amounts were allowed duty free :—

Duty free.	For every cwt. of cod, ling, or hake	50	lbs.	of	salt.
	Each barrel of wet cod, ling, or hake	56	„		„
	Do. „ of 42 gals. of salmon	36	„		„
	Do. „ of 32 „ of white herring ...	140	„		„
	Do. „ of 32 „ of red „ ...	65	„		„
	Do. „ of 32 „ of clean „ ...	56	„		„
	Do. last of 1,000 dried sprats	25	„		„
	Do. cask of 50 gals pilchards or scads..	336	„		„
	By 42 Geo. III, c. 93, s. 20.				
	For 32 gals. mackarel	84	„		„

The next thing which claims attention is free salt for agriculture. This is a measure much more difficult, than the last to devise, with safety to the revenue. Agricultural salt is taken to a distance to be used, and to many different destinations at one time. Even if it were possible to follow it, it is applied to the land in such a variety of ways, and at such various intervals of time, that it would be hard to pre-

vent fraud. Careful precautions must be taken, therefore, to prevent abuse of this privilege. The usual method of guarding agricultural salt, is to mix it with other chemical manures, before issuing it, charging accordingly. In Belgium, for instance, salt is mixed with gypsum or chalk to render it too impure for other purposes. A mixture of salt and "poudrette," or dried sewage, might safely be sold for agriculture, without any fear of its finding its way into the pot, and a capital manure it would make. Salt is admirably adapted for this purpose, owing to its antiseptic qualities; and this manure would cost little, where facilities for natural solar desiccation exist. In England, formerly, refuse salt was issued free for agriculture, intimately mixed up with soot. This mixture forms a black compost quite unfit for domestic use. It was particularly appreciated by the farmers, who attributed to it special fertilising powers. Other similar mixtures would be suggested by local conditions.

By a decree issued under the third French Empire, and signed by the then Minister of Finance, P. Magne, (8th November 1869,) salt was allowed to pass, free of duty, for cattle, agriculture, and the manufacture of artificial manures, in France, if denaturalised by certain processes, laid down. These processes to be carried out at the salines, salt depôts, or other localities named. The following is a translation of the processes of denaturalisation, recognised by the decree, and therein printed in full, in the order given.

"To 1000 kilogrammes of salt, reduced to powder, there must be added, at choice.

1·200 kilos of oil cake.

2·300 ,, pressed beet-root pulp, or fruit skins.

3·5 ,, red peroxide of iron, (colcotar, or Prussian red) and 100 kilos of oil cake.

4·5 kilos of peroxide of iron; 200 kilos of pressed beet-root pulp, or fruit skins.

6·0 „ of red peroxide of iron; 10 kilos of soot, or lamp black, 10 kilos of vegetable tar.

7·5 „ red peroxide of iron; 20 kilos of vegetable (*goudron*) tar.

8·30 „ ferruginous ochre, or mineral iron in fine powder; 30 kilos of tar from gas manufactories; 50 kilos guano, poudrette, fecal matter, dung (*d'etable consommé,*) or other manures of animal origin.

9·30 „ sulphate of iron; 120 kilos guano, poudrette, fecal matter, dung, (stable refuse) or other manures of animal origin.

10·60 „ of platre, (gypsum) raw or cooked, or *platras* in fine powder; 150 kilos guano, poudrette, fecal matter, dung, stable refuse, or other animal manure.

But all these precautions which unfit salt for human use, render it too impure for horses, cattle, sheep, etc. Hence, two kinds of agricultural salt become necessary when free salt is issued in the mixed state, manure salt and edible salt. Coloured salt is an expedient for getting over this difficulty. In Prussia, salt for agriculture is coloured pink, just as Government quinine for the use of Government Institutions is coloured pink in India. It may be coloured by wetting it with a saturated solution of salt dyed with infusion of beet-root, or cochineal, or tincture of red sandal-wood, or saffron; or it may be coloured with turmeric, the colouring matter of curry powder. This coloured salt is

perfectly wholesome for live stock. It has consequently the drawback of being equally good for human beings. Considering however that it could not be hawked about or sold; that it would only be issued to *bonâ fide* agriculturists upon bond; that it would colour food, especially rice, if mixed with it; the danger of fraud is not so great as it seems at first sight. Besides, in most countries, popular prejudices have to be reckoned with; and there is good reason to believe that oriental popular prejudices run strong in the matter of salt. These prejudices would be in favour of the revenue always. In Madras, for instance, there is a strong prejudice against Cheshire salt. Nothing would be better for Indian cattle than blocks of Cheshire rock-salt. Cheshire rock-salt could be laid down at Madras at a price which would place it within the reach of substantial farmers. It has these revenue advantages that it is kept in an exposed place, open to examination, and that the different effects produced, when licked by cattle, or broken off for the pot, are obvious in its condition at a glance.

In France, the making of blocks of hard crystal salt, for cattle, is a special branch of salt manufacture. In Cheshire, rock-salt is shaped into blocks for the same purpose. Under any circumstances the provision of free salt for agriculture is attended with some difficulty, and some danger to the revenue. It is a question of extra establishment, police, and vigilance. Some extra expenditure must be incurred; but nothing in comparison with the great interests involved. It is unjustifiable, moreover, and impolitic, to levy upon an agricultural race, a tax upon one of the prime necessaries of life and of agriculture, in such a way, as directly and indirectly, by action and reaction, to injure agriculture, and impoverish the people. It is killing the goose with the golden eggs.

Free salt for chemical manufactures is the third and last provision of enlightened salt laws. This provision is attended with comparatively little difficulty or danger to the revenue. Manufactures of the kind are few and far between. Where they do not already exist, Government has a right to assign them a locality, and veto their positions out of expedient bounds. Many carefully planned restrictions were attached to this privilege in the time of Geo. III., in England. By 43, Geo. III., c. 69, which imposed a duty of 10 shillings a bushel on salt, an allowance of 10 shillings a bushel was made to linen and cotton bleachers and hydrochloric acid manufacturers, deducting at the rate of 7½ per cent. in consequence of increased weight due to moisture. By 49 Geo. III., c. 81, s. 116. Glass and Alkali manufacturers may take salt upon bond being given that it shall be used in manufacture, such bond to be discharged on oath given that it was so used. S. 117. The salt must be delivered at the works in presence of an officer, who will see if the amount corresponds with the permit. S. 120. If the salt is less than the quantity stated in the permit, the manufacturer is held responsible for it. S. 120. An officer may inspect such chemical works, using free salt, at any time; but with a policeman, if at night. Obstructing the officer liable to a penalty of £50. When we consider the wealth and position of persons engaged in this class of business, whose interest it would be, equally with the Government, to prevent fraud, which would forfeit their bond and destroy their business at one blow, we see the security against fraud is in these cases great. There is no doubt that chemical manufacturers are strongly opposed to the tax on account of the friction involved in the regulations for safe guarding the revenue; but their objections are neither very unselfish, nor patriotic. Given free salt for chemical industries, for husbandry, and for fish curing;

together with a large revenue from salt; and the objectors to the tax are disarmed.

The quantity of free salt used up in France in the Arts and Agriculture equals 30 per cent. of the total quantity used in the country. This will give some idea of the importance of this subject, even in a quasi agricultural country.

The Prussian Government possess a monopoly of salt and sells it at the rate of a penny a pound for ordinary consumption. As at this rate it is too dear for agriculture, they provide at one-tenth of the above rate an equally good quality of salt, but stained pink by some harmless dye. It is found that this plan works well. Austria derives about £2,000,000 annually from her salt monopoly. Russia, although she has abandoned the tax, still forbids the importation of salt by Azoff and the Black Sea ports. A duty of ten kopeks per pood is levied on salt imported by Archangel, and on salt imported by other routes, 20 kopeks. A penny equals 5 kopeks, a pood is 36 lbs. Salt monopolies exist in Hungary, Italy, Turkey, and Spain. Portugal is free.

France.—Philip of Valois, 1342, enforced a salt tax to support a pressing need. It remained nevertheless as a standing tax. This was the beginning of the *Gabelle;* which afterwards developed into an irrational code of salt laws, which sent four or five thousand people annually to prison, or the galleys; and which finally helped to precipitate the French Revolution. At first only two derniers ($\frac{1}{4}$ farthing) in the lb. was levied; but in 1349 the tax was raised to six derniers. In 1366, Charles the Wise reduced the tax; and abolished it entirely in 1380. The Duc d'Anjou succeeded in re-establishing it in 1382, after suppressing a revolt of the peasantry. The tax caused much bloodshed, and was greatly disliked. The tax was then 20 livres per muid. When it was raised to 40 livres, the opposition became so violent that the Government were obliged to reduce it gradually. In the time of Louis XI. it stood at 15 livres per muid. It then rose until, in the reign of Francis, it stood at 45 livres. As regards salt, France was divided into three classes of provinces, Grand Gabelle, Petit Gabelle, and Free. The latter were free by reason of treaties made at the time they joined the French Nation. Henry II. tried to simplify matters by imposing a universal tax; but failed. In his reign many provinces bought themselves out of the Gabelle. The tax had risen

in 1680 to 2,160 livres per muid. (Dr. Schmidt, Das Salz, p. 58.) It required bloodshed to enforce it; and even the consumption of salt itself had to be enforced. Every man was obliged to take 3 livres 9 sous of salt a day, from the Royal Salt Granaries: and if he had a family 19 livres, 15 sous. Neckar, the celebrated Minister of Finance, was entirely opposed to the salt tax, and laboured at a scheme to replace it. He calculated in 1784 that the Gabelle produced a revenue of sixty million livres, or £2,625,000.

His tables show that the population of France was at that time 24,800,000; and the consumption of salt 3,450,000 quintals, of 108 lbs. English, each. In 1794 the salt tax was abolished by the French Revolution.

At present, the French Government do not make their own salt. There are a large number of salt manufactories on the Mediterranean Coast, and yet a larger number of small ones on the Biscayen Coast, possessed by individuals or by companies, as private property. These, make as much salt as they can without restriction or interference on the part of Government, but, for every ton of salt they sell in France, they have to pay the Government a *droit*, or duty, of one hundred francs. To insure the due collection of the tax, Government requires that the salt pans be arranged, and the salt stored, in a manner to enable the Customs Officers effectually to guard against smuggling and fraud. The Government itself maintains a guard of *Douaniers*, or Customs Police, at the pans, whose duty it is to prevent contraband, and to assist at the weighment of all salt delivered for home or inland consumption, and to note the amount. The tax is collected accordingly.

The Salt Customs Officials are chosen from the Army and none but soldiers who have received a good conduct badge are eligible for this service. The rate of pay in the Salt Department is higher than in the Army. No tax is levied on salt exported from France. If it be true that the cost of salt manufacture in France, including *all* charges, amounts only to five francs a ton, the duty levied is 20 times the value of the article.

The quantity of salt which paid duty in France in 1876 for consumption was 315,549 tons; exported 109,633 tons; delivered free for agriculture and the arts 183,763 tons; total 608,945 tons.

China.—The manufacture and sale of salt is a strict Government monopoly; neither imports nor exports being allowed. Salt is made

in the shallow lagoons along the coast by solar evaporation, in the manner described in Chapter XI. The salt is small grained and dirty, and probably mixed in an unusual degree with the ordinary impurities of sea salt. It is stored in large mounds at the seat of manufacture. Traders are licensed to purchase the salt in certain quantities for certain destinations, and they are obliged to sell it at a fixed price in the various provinces. The price of salt in the different provinces varies with distance from the sea; and also with the wealth and needs of the province. Each province has its separate monopoly in the article of salt. The price of salt at Shanghai is 2 shillings per pecul of 133 lbs. Salt is dearer, however, at Canton, perhaps double that price. Hong Kong, which is a free port, gets cheap salt from Siam. From large stores, maintained in Hong Kong, salt is smuggled into the neighbouring province of Canton, in junks. The salt monopoly administration is very extensive and complete. There are two or three High Commissioners of salt revenue. To prevent smuggling on the coast, the Government keep up a fleet of armed steam launches, in which Europeans are occasionally employed. The smugglers sail in fleets of 4 or 5 junks, well armed and manned, and have no hesitation in encountering a single steam-launch. Indeed, a single steam-launch will, as a rule, give a wide berth to such a fleet, since the salt smugglers are known to be of the fighting breed.

Loftie says, that in Egypt every man has to buy his salt from the Khedive, who has a monopoly of the manufacture; and very bad brown salt it is. Every man, woman and child, is bound to consume or at least to buy, 10 piastres worth of salt in the year.—*A ride in Egypt*, 1879, p. 300.

APPENDIX.

The following note on the subject of the philology of *salt*, is contributed by R. A. Neil, Esq., M.A., Fellow and Lecturer of Pembroke College, Cambridge.—"Skeat's new English Dictionary" gives *salt* as coming from the root S A R. This is, no doubt, universally received. The termination he takes as the *ta* of the past participle passive. All European Aryan languages seem to use cognate forms: *αλσ*, *sal, salt, salz;* Dutch, *sout;* Icelandic, Danish, Sweedish, *sult;* Russian, *sole;* Welsh, *hal;* Irish, *salann* and *saillte*, etc. But Zend and Persian show no word from this root meaning 'salt.' Sanskrit, though it has many words for this meaning, seems hardly to use any derivative of √ SAR (Skt. *sar* and *sṛi*) in this way.

V. Helm (author of the Kulturpflauzen and Hausthiere) has a tract, Das Salz, where he tries to show that the Aryans when undivided did not know of salt, the N. Aryans first finding it by the Aral, and Caspian.

Pictet (Origines Indo Europiennes, ed. 2, 1877) will not accept this, and seems rather inclined to a belief in the Aryan knowledge of the article."

W. W. Hunter, (The Non-Aryan Languages of India and High Asia) gives the following list of words denoting salt in different languages, grouped philologically:—

	Types.	*Salt.*
Inflecting.	Sanskrit	Lavaṇa.
	Arabic	Milḥ.
Compounding.	Bask	Gatz.
	Fumic	Suola.
	Magyar	So.
	Turkish	Tuz.

	Types.	*Salt.*
Compounding	Circassian	Zogho, Shugu.
	Georgian	Marili.
	Mongolian	Daboson, dabusun.
	Mantshu	Debsun, dabsun.
	Javanese, Ngoko	Uyah.
	Javanese, Krama	Sarim.
	Malay	Garam.
Isolating	Chinese, Nankin	Yen.
	Chinese, Pekin	Yen.
	Chinese, Canton	I'm.
	Chinese, Shanghai	Yen.
	Amoz, Colloquial	Jain.
	Japanese	Liwo.
Chinese Frontier and Tibet.	Brahni	Be.
	Gyámi	Yan.
	Gyárung	Chhe.
	Takpa	Tsá.
	Mányak	Cheh.
	Thochú	Cheh.
	Sokpa	Távoso.
	Horpa	Chháh.
	Tibetan (written)	Tshá.
	Tibetan (spoken)	Chhá.
Nepal W. to East	Serpa	Chhá.
	Súuwár	Yúsi.
	Gurung	Chácbá.
	Múrmi	Cháchá.
	Magar	Chá.
	Thákeya	Cháchá.
	Pakhya	Nún.
	Newar	Chhi.
	Limbu	Yúm.
Kiranti group (East Nepal.)	Kiranti	Yúm.
	Rodong	Rúm.
	Rungchenbung	Yúm.
	Chhingtángya	Yúm.

	Types.	*Salt.*
Kiranti group (Ea. Nepal.)	Nachhereng	Ram.
	Waling	Yúm.
	Yákha	Yúm.
	Chourásya	Yok si.
	Kulungya	Gum.
	Thulungya	Yo.
	Báhingya	Yúk̄ si.
	Lohorong	Yúm.
	Lambichhong	Yúm.
	Báláli	Yúm.
	Sáng-páng	Rúm.
	Dúmi	Ram.
	Khaling	Ram.
	Dungmali	Yúm.
B[illegible]	Darhi	Nún.
	Denwár	Nún.
	Pahri	Chihá.
	Chepang	Se.
	Bhrámu	Chhá.
	Váyu	Chia, jikhom.
	Kuswar	Nún.
	Kusunda	Huk vi.
	Tharu	Nún.
	Lepcha (Sikkim)	Vom.
	Bhutani *v.* Lhopa	Chhá.
N. E. Bengal.	Bodo	Shyúngkáre, sayúngkrī.
	Dhimal	Dese.
	Kocch	Nún.
	Garo	Syang.
	Kachari	Shoonkri.
East frontier, Bengal.	Munipuri	Thúm.
	Mithán Nágá	Hum.
	Tablung Nágá	Hum.
	Khári Nágá	Machi.
	Angami Nágá	Matse.
	Námsáng Nágá	Suru.
	Nowgong Nágá	Matsü.
	Tengsa Nágá	Machi.

	Types.	Salt.
East frontier, Bengal.	Abor Miri	A'lu.
	Sibságar Miri	A'llo.
	Deoria Chutia	Sün.
	Singpho	Jum.
Arrakan and Burmah.	Burman (written)	Ch'*há*.
	Burman (spoken)	S'*há*.
	Khyeng *v.* Show	Tsí.
	Kámi	Maloi.
	Kumi	Piloi.
	Mrú *v.* Toung	Wís'há.
	Sák	Súng.
Siam and Ten m.	Talain *v.* Mon	Po.
	Sgan-karen	Ithah.
	Pwo-karen	Tilah.
	Toungh-thu	Ta.
	Shan	Ko.
	Annamitic	Muôi.
	Siamese	Kál o, kleüa.
	Ahom	Klu.
	Khamti	Kéù.
	Laos	Keu, kem.
Cen a ndia.	Ho (kol)	Bulung.
	Kol (Singhbhum)	Bulung.
	Santáli	Bulung, khár á (adj).
	Bhumij	Bulung.
	Uráon	Bekh.
	Mundala	Bulang.
	Rájmahali	Beke.
	Gondi	Sabbar, Sawod.
	Gayeti	Sawod.
	Rutluk	Sawor.
	Naikude	Sup.
	Kolami	Sup.
	Mádi	A'wori howar.
Centi India.	Mádia	Howar.
	Kuri	Bulum.
	Keikadi	Upu.
	Khond	Vuppanga.

	Types.	Salt.
Central India.	Sávara	Basi.
	Gadaba	Bitti.
	Yerukala	Sonava.
	Chentsu	Nún.
Southern India.	Tamil (ant)	Caret.
	Tamil (mod)	Uppu.
	Malayálma (ant)	Caret.
	Malayalma (mod)	Uppu.
	Telugu	Uppu.
	Karnátaka (ant)	Caret.
	Karnâtaka (mod)	Uppu.
	Tuluva	Upp.
	Kurgi	Uppu.
	Todura.. Toda ...	Uppu.
	Kóta	Uppu.
	Badaga	Uppu.
	Kurumba	Uppu.
	Irula	Uppu.
	Malabar	Uppu, Lavanum.
	Sinalese	Lunu.

SALT STORMS.

On the 29th April, of the current year, (1882) a severe gale from the S. W. did considerable damage to vegetation in the South of England, for many miles inland. Its effects were attributed to salt, crystals of which were distinctly noticed by two independent observers, who wrote to the "Field" (V. 19, p. 662). One of these writers mentions the fact that a similar salt storm swept over Yorkshire, from the West, in 1839, and did much damage as far as Wassand, about 120 miles from the west coast. At a meeting of the Royal Horticultural Society (May 23, 1882) Dr. Church explained his experiments on the subject of salt storms, carried on during the last 15 years. He found from 5 to 7 grains of salt per gallon of rain, brought from the west by autumnal gales; whereas ordinary rain water contained only half a grain to the gallon. He mentions that the exposed sides of the trees in Oakley Park were injured by the salt, which

could be seen sparkling on the trees a few days after a gale, if no rain followed; and this at a distance of 25 miles from the sea. He thinks that salt acts by abstracting moisture from the leaf cells, and forming a concentrated solution, which in a manner pickles the leaf. Different trees were differently affected; but it was the general opinion of the meeting that this was due to different degrees of hardiness in the trees. Assuming that ordinary rain water in England contains half a grain of salt to the gallon, an inch of rain, would yield 11,315 grains per acre, and with an annual rainfall of 30 inches, 339,450 grains or 44lbs. per acre. We see from this that salt is hardly needed as an artificial manure in Great Britain. I think this also accounts for the wealth of grass lands in England and Ireland.

Bigg—Wither (*Pioneering, in Southern Brazil*, pp. 250 and 251) gives a most graphic description of the savage eagerness of the wild mules of South Brazil, at salting time. He says, "In obedience to a sign from the *feitor* the salt bags were opened, and the contents distributed on the ground in several little heaps, at sufficient distances apart. Now the battle commenced. All respect, even towards their foster parent (an old gray mare), was forgotten in the intense eagerness of each animal to reach the salt. The law of the strongest and most courageous was paramount in the wild medley that ensued. Now, one mule, with ears well laid back, and mouth wide open, would charge into the excited throng, and lash out with tremendous force, fury, and rapidity, clearing a complete ring round it for one brief minute, during which it would have the salt heap all to itself. Short was the time allowed it. Another mule, rendered frantic at the sight of the salt disappearing, would charge into the circle, and a savage duel would commence, during which other animals would slip in, and, meeting each other, all again would become an indescribable scene of dire fighting and tumult The blows given and taken were something frightful to witness, yet, as far as I could see, no animal exhibited any sign of pain, but again and again each would return to the charge furiously eager for the salt. It was remarkable that no mule would allow another mule to lick at a salt heap at the same time as himself. Fighting, therefore, could not have been avoided by any practicable multiplying of the number of heaps.

The same author mentions that the mirim bees, which make a delicious honey, on a diet of decaying animal matter, often covered the *Xarqui* and the *touchino* of his men, more than half an inch deep, attracted to these dried foods by the salt which they contained. (Vol.

I, p. 305). He also makes a remark which I think fairly illustrates the growth of the idea that man can exist without salt; and is in some cases injured by it. After describing the wild Botocudo Indians, of the forest, as living on raw tree-maggots, wild fruit, and tapir flesh, half broiled, he proceeds to remark of 24 of them who died in a few days, after having been brought into his camp and liberally fed, that they were probably killed by salt, to which they were unused. It is clear however that they got salt in tapir flesh, if not in other ways, and that their unusual diet, in captivity, gave rise to the dysentery which carried them off.

Measures and Weights of Water, from "Parke's Hygiene."

The following are some useful measures and weights of water (at 60° Fahr.):—

1 cubic foot of pure water,		=	1728 cubic inches.
"	"	=	6·2355 gallons (say 6·23).
"	"	weighs	62·35 lbs. avoir. at 62° F.; and this is the pressure of a *cubic foot* of water on each square foot.
1 gallon,	"	=	277·274 cubic inches, or 0·1604 cubic feet.
"	"	weighs	70,000 grains, or 10 lbs. at 60° Fahr.
1 imperial pint,	"	=	34·65923 cubic inches (say 34·66).
" "	"	weighs	8750 grains.
1 imperial ounce,	"	=	1·733 cubic inches.
1 imperial ounce of pure water		weighs	437·5 grains.
1 cubic inch	"	weighs	252·558 grains.
100 cubic inches,	"	weighs	57·7 ounces (avoir.)
1 French litre,		=	0·2200767 gallons.
1 French litre of pure water,		=	61·027 cubic inches.
1 Gallon	"	=	4·5434 litres (say 4·54).
1 Ton	"	=	35·84 cubic ft., or 224. gallons.
1 lb. Avoir.	"	=	·000446 = tons.

AVOIRDUPOIS.

For all Common Goods.

16 Drams - - -	make	1	Ounce (*oz.*)
16 Ounces - - - -		1	Pound (*lb.*)
14 Pounds - - - -		1	Stone.
28 Pounds - - - -		1	Quarter.
4 Quarters (112 lbs.)		1	Hundredweight (*cwt.*)
20 Hundredweight - -		1	Ton = 2240 lbs.

SURFACE.

144 Square Inches	make	1	Square Foot.
9 Square Feet - - -		1	Square Yard.
30¼ Square Yards - -		1	Sq. Rod, Pole, or Perch.
40 Perches - - - -		1	Rood (*R.*)
4 Roods (4,840 sq. yds.)		1	Acre (*A.*)
640 Acres - - - - -		1	Square Mile.

SOLIDITY.

1,728 Cubic inches	make	1	Cubic Foot.
27 Cubic Feet - - -		1	Cubic Yard.
147,197,952,000 cubic ft. -		1	Cubic Mile.

Formula for converting Centigrade temperatures into Fahrenheit.
Multiply by 9, divide by 5, and subtract 32 from the result.

For converting Fahrenheit in Centigrade.
Subtract 32, and take five-ninths of the remainder.

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